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Carbon Dioxide Removal: from International Conceptualisation to National Policy – a Norwegian Case Study

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Declaration

I, (name), declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature…Martin……………………………..

Date…10.05.2022……………………………

Abstract

It is becoming increasingly evident that reaching the 1.5° or 2° C targets set out by the Paris Agreement requires large quantities of CO2 to be removed from the atmosphere using Carbon Dioxide Removal (CDR) solutions. However, there is a large discrepancy between the scale-up of CDR portrayed in climate scenarios that limit warming in line with the climate targets and the actual pace of global CDR deployment. Based on a qualitative desk study, this thesis combines empirical data and existing literature in a case study on CDR implementation in Norway. First, it investigates practical, social, and political barriers and opportunities to implement CDR on a national level. Second, it examines how CDR is evolving in the Norwegian policy regime, and lastly, it analyses policy instruments used in other countries and hence proposes policy instruments that could enable deployment in Norway. The results of the analysis suggest that the country holds favourable conditions to implement CDR and that policy instruments could effectively scale up the deployment.

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Glossary of terms

Additionality refers to that an emission reduction or removal is additional to what would have been achieved without a mechanism such as a carbon offset. In other words; the reduction/removal would not have taken place in the absence of the respective incentive (Jeffery et al., 2020).

Hard-to-abate refers to industries that are difficult to abate, due to various reason such as high costs or advanced technology required.

National GHG Inventories refers to national accounting of greenhouse gas emissions and removals that Parties to the United Nations Framework Convention of Climate Change are required to submit annually.

Net-negative refers to when emissions are reduced beyond net-zero when carbon dioxide removal technologies are used to remove more CO_2 than what is emitted to the atmosphere (Fuss et al., 2020).

Policy design refers to the process of creating policy goals and objectives and implementing policy measures to achieve those goals.

Permanent CDR refers to methods of storing sequestered CO_2 for at least 1000 years.

Sink refers to a process that removes CO_2 from the atmosphere.

The permanence of storage or *durability of storage* refers to how long sequestered carbon is estimated to be stored.

Abbreviations

CDR - Carbon Dioxide Removal

CCS - Carbon Capture and Storage

BECCS - Bioenergy with CCS

DACCS - Direct Air Capture with CCS

GHG - Greenhouse gas emissions

Gt - Gigatonne

Mt - Million ton

NET - Negative Emissions Technology

SR1.5 – 2018 IPCC special report on the 1.5° C Global Warming

1.0 Introduction

Limiting global warming to 1.5° C above pre-industrialised levels requires severe societal transformations to rapidly reduce CO_2 emissions (IPCC, 2018). Additionally, Carbon Dioxide Removal (CDR), the art of removing CO_2 from the atmosphere, is increasingly being seen as a necessary tool to stabilise global CO_2 concentrations. Scholars remark that there is now little chance of reaching the climate targets set out in the Paris Agreement by only reducing current emissions (Geden & Peters, 2017). Most emission scenarios and climate models consistent with limiting warming to 1.5° or 2°C rely on large-scale deployment of Carbon Dioxide Removal (CDR) within the next decades, to compensate for ongoing emissions and CO_2 already emitted to the atmosphere (Anderson & Peters, 2016). This can be done by making use of technological and nature-based solutions to physically remove CO_2 from the air and durably store it. However, the near-term ramp-up of CDR suggested by the scenarios is not reflected by national policies (Minx et al., 2018). Today, most discussions on CDR have remained at the academic level (Geden & Peters, 2017). The lack of CDR effectively being implemented can be explained by several factors. The most general is that the removal of CO_2 is merely a public good, consequently, there isn't a market demand driving investments and subsequent implementation. Secondly, countries are still struggling to abate ongoing emissions, thus paying to remove CO_2 already emitted to the atmosphere might appear as a premature measure to policymakers.

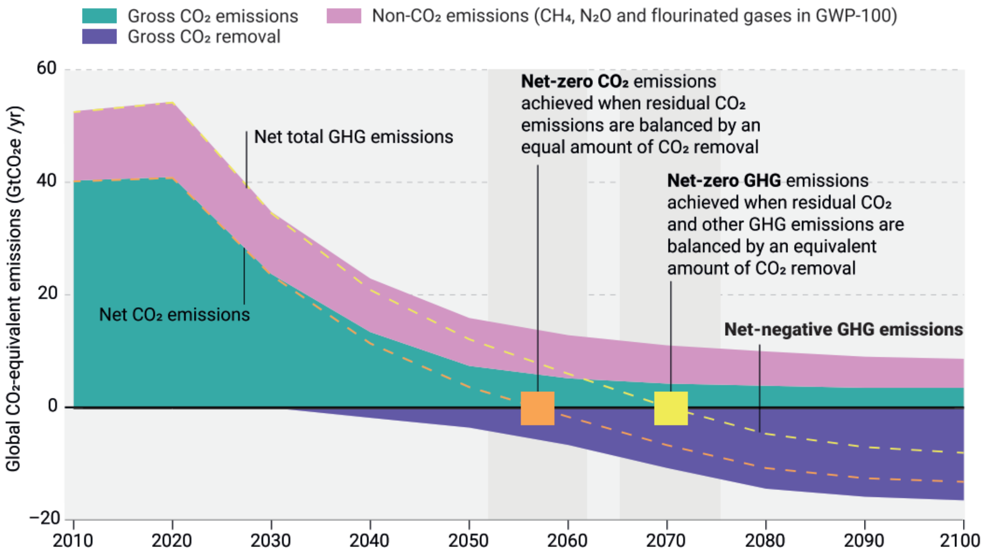

Figure 1: illustration of GHG mitigation pathways and the role of CDR in keeping warming well below 2 degrees. Source UNEP (2021)

However, to reach the gigaton scale needed to be in line with the international climate targets, substantial political action to incentivise CDR deployment is needed alongside the actions to reduce CO_2 emissions. Researchers suggest that progressive and industrialised countries need to take on the leadership role to develop and start the implementation of CDR methods (Honegger & Reiner 2021). Norway is a resourceful and industrialised country that has been a pioneer in developing Carbon Capture and Storage (CCS) technology - which is an integral part of technological CDR solutions (Schenuit et al., 2021). The country also has large parts of the emission cuts ahead of it to achieve its goal of cutting 55% by 2030 and 90-95% by 2050 compared to 1990 levels, as it has only cut 4% of the respective emissions (SSB, 2020). Accordingly, Norway appears as a suitable candidate to take on such a role. A scale-up of CDR in Norway can both contribute to reaching national climate targets in the near-term and international targets moving towards 2050. As such, this thesis will explore the broad issue of CDR from different angles, using Norway as a case study to operationalize the necessary steps to formulate national policy.

The academic literature on CDR portrays a wide array of barriers to large-scale deployment of the specific CDR solutions, spanning from the different associated resource-use and costs to more broad political implications such as public acceptance. Nonetheless, the literature also reveals that there are substantial opportunities and co-benefits to CDR approaches, such as the possible positive side-effects of reforestation on biodiversity by restoring habitat, and the cost reduction projected for direct air capture technologies. However, CDR is a very broad-ranging concept, it involves several inherently different methods that are researched within a wide span of disciplines, consequently making the literature on CDR relatively fragmented.

To structure the research this thesis uses a case study approach to collect the necessary information to inform policymaking. Drawing upon previous research and empirical data, this thesis takes the form of a case study on CDR in Norway. The research consists of three steps that lay the ground for a discussion of suitable policy options to stimulate CDR approaches being taken in use. First, it investigates barriers and opportunities that can restrict or promote deployment, secondly, it analyses how CDR is integrating into Norwegian politics, and thirdly it gives an overview of policies in other countries that are used to incentivise CDR deployment.

2.0 Background

2.1 Literature and concept definitions

CDR is here understood “as intentional human efforts to remove CO_2 emissions from the atmosphere” (Minx et al., 2018 p. 3). That is the additional efforts on top of what the natural processes already sequester (Minx et al., 2018b). CO_2 can be removed from the atmosphere by using an array of different methods. For clarity reasons, this thesis will use the frequent categorisation of such methods as either ‘technological’ or ‘nature-based’ approaches or solutions to deliver CDR, even though the separation might be inherently faulty as it is hard to distinguish what is natural and what is not natural (Bellamy & Osaka, 2019). Nature-based approaches are methods that enhance and preserve CO_2 storage in terrestrial and aquatic ecosystems (Matthews et al., 2022). Nature-based methods range from more mature solutions such as afforestation to less practised and more conceptual solutions such as enhanced weathering and ocean fertilisation (IPCC, 2018). There are two prominent technological solutions that are believed to be able to remove substantial amounts of CO_2. 1) Bio-Energy with Carbon Capture and Storage (BECCS), a method where biomass that has grown and sequestered CO_2 is burned to produce bioenergy. Before combustion and release into the atmosphere, the CO2 is captured and then stored for a very long time (IPCC, 2018). It is believed to be a prominent method in the near term since the proponents of it; bioenergy and CCS are well known and demonstrated on the scale (Fuss et al. 2021). Carbon Capture and Storage (CCS) is the process of using technology to capture CO_2 at emission point sources and thereby injecting the CO2 into geological storage. 2) Direct Air Capture with Carbon Capture and Storage (DACCS) is a method to filter out CO_2 from the air using chemicals followed by storing the captured CO_2, it is still in the early commercialisation phase but is believed to be a prominent technology in the medium to long-term due to less water and land restrictions compared to other solutions, and because of expected technological learning (Realmonte et al., 2020). ‘Negative emissions’ and ‘Greenhouse Gas Removal’ are synonyms for Carbon Dioxide Removal (CDR), but this thesis will use CDR because the concept precisely describes what the methods are used for.

An important concept in the discussion of CDR is the difference between biogenic and fossil emissions. Human-induced climate change has led to an increasing accumulation of CO_2 concentrations in the atmosphere which again leads to a rise in the global mean temperature

(IPCC, 2018). The accumulation is mainly caused by the burning of fossil fuels that have been stored underground for millions of years, these are termed fossil emissions (IPCC, 2021). On the other hand, when biomass is burned - such as wood - CO_2 is also released into the air. However, these are called biogenic emissions, stemming from biological material, and are not required to be included in the national greenhouse gas (GHG) inventories submitted to the United Nations Framework Convention on Climate Change (UNFCC) because they are a part of what is termed the natural carbon cycle (The Royal Society, 2018). The natural carbon cycle refers to the process where CO_2 is cycled between the atmosphere and biomass. When biomass grows it sequesters CO_2 through photosynthesis and when it decays or is burned it releases CO_2 back into the atmosphere. However, if biomass is sourced sustainably, new biomass grows up again and in principle draws back an equal amount of CO_2 creating a CO_2 cycle (The Royal Society, 2018).

This differentiation is important because when Carbon Capture and Storage (CCS) is deployed on a plant that releases fossil CO_2 it leads to what is termed emission *avoidance*, which refers to emissions that otherwise would have been emitted being avoided. When CCS is deployed at a plant burning or converting biomass it leads to emission *removal* because the capture and storage of biogenic CO_2 take CO_2 out of the natural carbon cycle, consequently reducing the total amount of carbon in the atmosphere (The Royal Society, 2018).

2.2 Scope & research gap

Research on CDRs has been around for decades, but it was the 2018 IPCC special report on the 1.5° C Global Warming (SR 1.5°) that established the magnitude of the need for CDR to reach the 1.5° and even 2°C targets (Möllersten et al., 2020). The special report looked at the impacts of warming above 1.5°C above preindustrial levels and subsequent mitigation pathways consistent with reaching the climate targets set out by the Paris agreement (IPCC, 2018). Temperature overshoot refers to when a target is allowed to be exceeded in a certain period. Many of the climate scenarios put forward in the SR 1.5° consistent with reaching climate targets entail global temporary temperature overshoot, which is later compensated for by CDR to make the temperature decline again. However, climate scientists warn about many unknown and irreversible climate risks on for example ecosystems generated such a temperature overshoot, the preferred pathway is thus to reach climate targets with little or no overshoot (Drouet et al., 2021). Scenarios put forward in the report that reaches the target with little or no temperature overshoot, still use CDR at a gigaton scale, ranging from 100-

1000 GT CO_2 removed within this decade (Möllersten et al., 2020). In comparison, to understand the proportion of these numbers, global energy-related CO_2 emissions reached 33 Gt in 2021 (IEA, 2021).

In the IPCC's scenario's BECCS and afforestation are the only CDR methods specifically mentioned (IPCC, 2018) (Waller et al., 2020). However, it is contested if the vast use of BECCS and afforestation is realistic due to the large areas of land it demands to produce the necessary biomass (Fuss et al., 2014). Anderson & Peters (2016) note that the deployment of biomass assumed in most Integrated Assessment Models (IAM) demands land areas the size of India times two (Anderson & Peters, 2016). However, climate modelling teams and researchers include and propose a wider range of additional CDR methods that have the potential to remove substantial amounts of CO_2 from the atmosphere, where DACCS is one of the most prominent ones (Minx et al., 2018; Anderson & Peters, 2016). As such, it is proposed that developing a portfolio of different solutions, each deployed at a modest scale, is more likely to deliver the necessary CDR sustainably, and contribute to reaching the climate targets (Minx et al., 2018; Anderson & Peters, 2016).

Despite the salience the technologies are given in integrated assessment models (IAMs) and climate scenarios, the technology is far from on the scale it needs to be. Today there exists globally only one large-scale BECCS plant and one large-scale DACCS plant is in the process of being built (Tamme & Beck, 2021; IEA, 2021). Moreover, emissions from land-use change such as deforestation are still increasing, consequently leading to a decrease in the uptake of CO_2 in ecosystems. Implying that large-scale CDR deployment remains as a hypothetical concept (Carton et al., 2020).

A rapid scale-up of CDR also presents multiple challenges. One fundamental challenge to deployment is that CO_2 is not valued in the current market, and the removal of CO_2 involves varied but substantial costs. Since CO_2 is not a demanded entity in the market but rather merely a public good, deployment will require the mobilisation of regulatory and financial incentives to enable the scale-up necessary (Fuss et al., 2020). Although many countries have set net-zero targets, which entails a balancing of reducing emissions and removing emissions (Honegger et al., 2021), there are currently few countries with specific CDR policies (Schenuit et al., 2021). The discrepancy between the CDR deployment in the near-term proposed in climate scenarios and actual political commitment through policy enablers has been termed an *incentive gap* and *implementation gap* (Poralla et al., 2021)(Fridahl et al., 2020)(Fuss et al., 2020). Fuss et al. (2020) identify that the main research gap concerning CDR is governance, policy, and acceptability (Fuss et al., 2020 p.145). Furthermore, Schenuit et al. (2020, p. 1) point out that *"The scientific literature on CDR governance and policy is still rather scarce, with empirical case studies and comparisons largely missing*". As an effort to contribute to filling this research gap, this thesis addresses the issue using a qualitative approach to bridge the gap between academia and policy. It combines existing knowledge and empirical developments embedded in a case study to explore how knowledge of CDR can be operationalised to national policies in Norway. It does not neglect that there are other possible roads to scale up CDR in Norway, this thesis proposes one of the potentially many possible pathways. It does so by reviewing policies used in other countries and policies suggested in the literature to scale up CDR to discuss their suitability in a Norwegian context.

2.3 Research questions and objectives

Objective 1: The main objective of this thesis is to explore suitable policy designs to enable the deployment of CDR in Norway, so the following research questions will guide this thesis.

Main Research Question (main-RQ): What policy instruments can incentivise Carbon Dioxide Removal in Norway?

To inform and give context to the analysis of policy instruments, the following sub-research questions are developed:

> **Sub-research question 1 (Sub-RQ 1):** What are practical, social and political barriers and opportunities identified in the literature to scaling up CDR that may inform national policymaking?
>
> **Sub-research question 2 (Sub-RQ2):** What are the main elements of the CDR regime in Norway?

Here the *CDR regime* refers to the political context into which CDR fits in, the governance structures around it and the industry and civil society actors who influence its development.

Objective 2: Secondly this study will explore suitable policy designs that can ensure wider deployment.

> **Sub-research question (Sub-RQ3):** What policy designs are used to scale up CDR in other countries and how can changes in regulatory measures incentivise CDR deployment in Norway?

3.0 Methodology

A researcher can't be entirely objective. However, a researcher should strive to prevent personal beliefs and values from distorting the material and be self-reflective and open about decisions that are made during the research process (Bryman, 2016, p., 35). The main RQ of this thesis is already somewhat biased, it takes for granted that CDR should be scaled up in Norway. However, this is a necessary and purposive premise to move beyond the debate of whether to deploy CDR and move towards evaluations of how it can take place. Subsequently, the thesis is normative, but throughout the thesis, I argue why CDR is a necessary strategy to reach the climate targets and answer the most prevalent criticism of the concept. To exhibit reflexivity, this chapter aims to describe and justify the choices made in the process of designing this research

3.0.1 Choice of topic and research questions

I have been interested in environmental and climate issues for a long time and have worked for several environmental organisations during and in between my studies. I learned about carbon capture and storage (CCS) during these occupations and found the topic both important and intriguing. When I started my current master's course, I wrote my first paper on the issue of carbon capture and storage in the master's course called 'Climate change and development'. One year later, as a part of the degree, I got an internship at the environmental organisation The Zero Emissions Resource Foundation on a project related to CDR. Initially, I already wanted to write about CDR for my thesis, but I needed more knowledge to identify relevant research gaps. A part of the internship was to write a literature review on CDR, during the process it became clear that national policies are largely missing. This internship therefore clearly influenced the choice of research questions and has contributed to widening my knowledge. My colleagues have also been resourceful in the process of identifying issues and clarifying uncertainties occurring when writing up the study. A general note is that there have been many developments in the field throughout the writing up of the thesis that necessitated an iterative process and have resulted in some alterations of the content late in the process.

3.0.2 Justification of methodological approach

Most of the papers I have written during my studies have been very theoretical. Writing my master thesis, I wanted to challenge myself by writing a more practical contribution useful to policymaking. Policymakers are increasingly faced with complex issues to be solved, especially in the case of environment and climate issues, where the answer to the problem often requires complex evidence. The choice of method was based on an effort to 'bridge the gap between academia and policy making' (Wiek et al., 2012) so that policymakers can benefit from a range of interdisciplinary evidence available. However, creating this bridge necessitates presenting some technical information on the topic to provide a holistic and in-depth understanding of the issue in question. The thesis contributes to value-adding to the field by combining existing theory with empirical data in a desk study to generate new knowledge.

3.1 Research strategy and design

The overall research method chosen for this thesis is an inductive qualitative approach based on primary and secondary sources. The qualitative approach refers to the method where the research is concerned with text, words, and concepts rather than numerical accounts. Inductive refers to the strategy of generating theory from data (Bryman, 2016). To answer the main research question, the research design chosen is an exploratory case study on the implementation of CDR in Norway, which entails exploring CDR in-depth from three different angles represented by the sub-RQs. Furthermore, in a case study approach, the unit is interesting on its own (Bryman, 2016), and the method is regarded as a useful strategy to provide access to policy interventions (Flyvbjerg, 2006). Generalisation is not the aim of a qualitative case study, rather it seeks "to reveal the unique features of the case"(Bryman, 2016, p.,61). The sampling of the respective case was chosen on the basis that Norway is a 'unique case' (Bryman, 2016, p. 62). The country is unique in the context of CDR because it holds favourable conditions for implementing technological CDR; long experience with CCS, access to renewable energy, CO_2 storage capacity, resources, and competence. Also, it has relevant features to secure and increase nature-based CDR due to its large terrestrial and ocean carbon sinks. The case was also chosen because it holds traits of being an ‘exemplifying case’, which refers to a case that exemplifies a broader context of which it is a member (Bryman, 2016, p.62). Most climate scenarios and pathways display widespread deployment of CDR internationally within 2050, in such, the case can serve as an example of one possible path to implement CDR policies in Norway and beyond. Lastly, the author has relevant background knowledge about the country useful to the topic, as well as access to data that is only available in Norwegian.

To answer the research questions, the data selected for this thesis are journal articles, official government documents and reports. The journal articles are used to derive theoretical concepts but also as sources of data for compressed descriptions of empirical developments. The official government documents are used as sources of empirical evidence. To generate the necessary data, a mix of contingent purposive sampling and snowball sampling strategies was used. Purposive sampling refers to the method of strategically collecting data that are relevant to answering the research question, and contingent refers to the criteria for sampling data that evolve throughout the research (Bryman 2016, p. 410). Snowball sampling refers to the method of collecting literature where a small sample of initial data relevant to the research question is collected and through its citations and references further relevant research is discovered (Bryman 2016, p. 415). Since purposive and snowball sampling are non-probability approaches it is not possible to generalise the result to a wider population (Bryman, 2016, p. 408). Even though the results from this case are not generalisable, the findings may serve as a departure for further research and other case studies. The targeted audience for the study is mainly Norwegian policymakers but also scientists, civil society actors and others interested in the topic from around the world.

All the sources are public and found online, and therefore easily retrievable by others. The availability of the documents used in this analysis strengthens the validity of this thesis. Getting affiliated with the literature was time-consuming and a large part of this project. To keep track of all the relevant literature I used the reference manager Mendeley to sort the literature into folders based on their topic, creating a database of literature. Based on the literature downloaded, Mendeley also gave me email updates on new and relevant literature on the topic making this thesis relevant and topical.

3.2 Sub-RQ1 – Research strategy and analysis

Sub-RQ1 aims to provide a holistic outline of barriers and opportunities to implement CDR in Norway. It operationalises both practical and theoretical knowledge on CDR that is relevant to the formulation policy. The analysis of sub-RQ 1 is divided into two sections firstly covering practical barriers and opportunities to specific CDR approaches, then it discusses theoretical concepts that represent the social and political barriers and opportunities.

To generate the necessary data, an extensive review of literature from different disciplines was necessary to understand the main issues relating to the topic. At the beginning of the research phase, general search words such as "Carbon Dioxide Removal" and "negative emission technology" together with "costs" "risks" and "potential" led me to find three highly regarded and cited articles "*Negative emissions—Part 1: Research landscape and synthesis*" (Minx et al., 2018), "*Negative emissions - Part 2: Costs, potentials and side effects*" (Fuss et al., 2018), and "*Negative emissions - Part 3: Innovation and upscaling*" (Nemet et al., 2018) which is a series of articles comprehensively and systematically assessing the academic literature on CDR. The authors of the series - consisting of 19 researchers from six countries - synthesise the most important findings from qualitative and quantitative literature on CDR. The three contributions each dive into relevant pressing issues of CDR with a different focus to define its role in global climate mitigation. "*Negative emissions - Part 2: Costs, potentials and side effects*" were the most useful to inform the section on practical limitations to specific CDR methods. The article comprehensively characterises each solution and goes through the potential of the different technologies. During the writing of the analysis, I also found a recent article *"Technology Readiness Assessment, Costs, and Limitations of five shortlisted NETs - Accelerated mineralisation, Biochar as a soil additive, BECCS, DACCS, Wetland restoration"* (Möllersten & Naqvi, 2022). This is a comprehensive and up to date review of CDR solutions which is one of the main sources of the section "practical barriers and opportunities".

To find literature covering social and political factors that affect the implementation of CDR I searched for "Carbon Dioxide Removal" together with "policy", "politics" and "governance". By using the snowballing strategy, a range of different sources were found by following citations. Additionally, an influential source of sub-RQ1 has been the report *"Greenhouse Gas Removal"* commissioned by the UK government, written by the two academies: the Royal Society and Royal Academy of Engineering. The report identifies "the range of available greenhouse gas removal methods, the factors that will affect their use and consider how they may be deployed together to meet climate targets, both in the UK and globally" (The Royal Society, 2018). The report is inter-disciplinary and thoroughly assesses several aspects useful to this thesis.

To analyse the data a thematic analysis of journal articles was employed. Thematic analysis is a framework to identify recurring themes or concepts in data, and the themes are then used to provide a theoretical understanding (Bryman, 2016, p. 586). In this chapter, the themes refer to the concepts found in the literature that can be identified as barriers and opportunities within the selected CDR approaches but also wider social and political concepts. Practical barriers and opportunities entail the specific issues related to each of the described CDR approaches. Social and political barriers and opportunities on the other hand involve broader social and political implications such as public perception and mitigation deterrence.

Thematic analysis can be employed in several ways, and since there is not a single specific procedure to generate the themes, Bryman (2016) emphasises that it is important that the researcher present the process whereby the themes were generated (Bryman, 2016). To increase the trustworthiness of the analysis, I will followingly justify the selection of themes by describing the search and selection process. The practical barriers and opportunities presented in sub-RQ1 were selected upon two criteria using an exploratory approach; 1) What are most frequently mentioned in journal articles that can be identified as barriers and opportunities, and 2) which of whom are relevant to the context (Norway) and policymakers. Throughout the research process, tentative themes were written down in a document. The final collection of themes was settled when saturation was reached, in other words when no more relevant concepts occurred when searching for literature. The CDR approaches that are analysed in detail were selected because they are most frequently referred to as the most mature methods, they are thus relevant because they are ready to be deployed if given some financial or regulatory incentives.

I do not attempt to state that all potential barriers and opportunities are covered in this research nor that all details are included. However, this chapter aims to give a general overview of the most significant ones that can inform policy and thus be relevant to policymakers.

3.3 Sub-RQ2 - search strategy and analysis

The choice of new policy designs is nested in existing governance structures. Consequently, existing policy measures and developments can reveal some overarching institutional objectives and philosophies that can guide the choice of new suitable policy designs (Vonhedemann et al., 2020). Hence, to consider country-specific traits when proposing policy, this chapter aims to look at which role CDR has in the Norwegian climate policy regime. The chapter is divided by developments in technological and nature-based CDR solutions. On both topics, there is a summary of key historic CDR-relevant policy events and thereafter an overview of the latest development in CDR policy.

The search words “Negative emissions”, “Carbon Dioxide Removal”, “Carbon Capture and Storage” and “Nature-based” were coupled with “Norway” or “Norwegian” and “policy” or “politics" to generate the data material for sub-RQ2. Journal articles such as “The growth of political support for CO_2 capture and storage in Norway" (Tjernshaugen, 2011) and “When climate policy meets foreign policy: Pioneering and national interest in Norway’s mitigation strategy”(Røttereng, 2017) are articles that describe and explain fundamental developments in the Norwegian climate policy regime relating to technological CDR developments and were key sources of data to the historic perspective in sub-RQ2. “Buffering Climate Change with Nature " (Hessen & Vandvik, 2022) were useful to describe recent policy developments on nature-based approaches. Generally, official government documents and some reports were used as sources to document policy developments.

This chapter does not try to cover every policy effort that relates to CDR nor all industry and civil society activity on the matter. Rather it aims to give an overview of the most important developments to provide the context to answer the second question in sub-RQ3 “how can changes in regulatory measures incentivise CDR deployment in Norway”.

When analysing structural change into sustainability, changes will most likely not have one causal explanation. Since sustainable technology is often not demand-driven like traditional improving technologies, the multi-dimensional interactions between technology, politics, the private market, and civil society become especially important (Geels, 2011).

The analysis of Sub-RQ2 was therefore influenced by the multi-level perspective (MLP) to encompass developments on different levels from different actors, however, due to the scope of sub-RQ2 the full framework and interpretive tools were not employed. The MLP is a social-science analytical framework that is used to understand transition pathways

(Esmailzadeh et al., 2020). The theory is interdisciplinary in that it is influenced by evolutionary economics, technology studies and social sciences. It conceptualises the dynamics patterns enabling socio-technical transitions from one system to another (Geels, 2011, p. 27). The concept 'Socio-technical transitions' refers to transitions that are enabled by intertwined social and technological developments. The MLP understands transitions as a non-linear process that are an "outcome of alignments between developments at multiple levels" (Geels & Schot, 2007, p. 399). The three levels are the *socio-technical regimes, exogenous socio-technical landscape,* and *niche innovations*.

The *socio-technical regime* forms deep structures on the meso-level that support the existence of the current regime with rules and regulations, but also cultural values and shared beliefs (Geels, 2011). Technological development often occurs incrementally with small adjustments over time (Geels, 2011). The developments are enabled by actors within the regime which consists of technological communities, policymakers, scientists, interest groups and civil society, with their individual and shared routines, institutions, and alignments (Geels & Schot, 2007, p. 400). The concept aims to trace the coordination of the different sub-regimes (Geels, 2011). The *Exogenous socio-technical landscape* forms the macro level and represents the wider context. Landscape developments refer to exogenous factors putting pressure on the existing regime, "such as oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems" (Geels, 2002). Influences beyond the control of regime actors and practices. Lastly*, niche innovations* which form the micro-level refer to emerging technologies developed within small networks of actors (Geels & Schot, 2007, p. 400). The niche innovations can either be symbiotic or disruptive to the existing regime (Geels et al., 2016). The chapter includes some important developments on the niche and landscape level but has given most space to the regime level "because transitions are defined as shifts from one regime to another regime." (Geels, 2011, p. 26) Developments on the different levels are presented intertwined throughout the chapter.

3.4 Sub-RQ3 - search strategy and analysis

The aim of sub-RQ3 is first to give an overview of national policy efforts on CDR around the world to form the basis for the subsequent discussion on relevant policy measures to incentivise CDR in Norway. The selection of countries, that have or have proposed policies on CDR, was influenced by the journal article "Carbon Dioxide Removal Policy in the

Making: Assessing Developments in 9 OECD Cases" (Schenuit et al., 2021) which gives a systematic overview of political CDR developments in 9 countries that are members of the Organisation for Economic Co-operation and Development (OECD). The countries were selected because they are the only countries to the author's knowledge that have policies to incentivise CDR. However, there could be countries with policies that are missed. Switzerland and Ireland are currently formulating policies, but I could not find detailed accounts about the policy design, so they were excluded. The EU was included, even though it is not the country, because it formulates policy and strategies on behalf of the member countries that are highly relevant to this study. Norway is not a part of the EU but is a part of the EU Climate Laws through its membership in the European Economic Area (EEA). Thus, regulations and frameworks that are developed by the EU directly apply to Norway.

Furthermore, to find additional data on policy developments I used the IEA's policy database to filter out policies on 'carbon capture utilisation and storage. The database describes and links to developments and decisions on the matter (IEA, 2022). Together with this database I also used the webpage www.cdrlaw.com, which is a "bibliography of legal materials related to carbon dioxide removal and carbon sequestration and use" (Sabin Centre for Climate Change Law, 2022). The bibliography is made in collaboration between Columbia Law School New York and the Sabin Centre for Climate Change Law. Both resources were highly helpful to find the necessary data. The latter also has a resource bank where journal articles on CDR are published, and it has a search and filter function making it easy to navigate to find relevant articles. The latter were used to find articles relating to all topics in this research. The sources used to describe the policies vary, from legislation to government inquiries, in addition to journal articles.

The aim of part two of this sub-research question is to assess different policy instruments and propose regulatory changes that could incentivise CDR in Norway. Schenuit et al., (2021) in an introductory literature review in their article give an overview of key insights on CDR policy and governance literature by mentioning the most influential papers on the issue (Schenuit et al., 2021, p., 3), which enabled the discovery of many of the articles used in this chapter. The discussion of policy instruments is based on the policy instruments derived from the analysis of policies in other countries.

To evaluate the policies, the following four criteria, which will be elaborated further on in the analysis, will be employed: *Administrative feasibility*, *Political feasibility*, *Cost-effectiveness*, and *environmental effectiveness.* The criteria are influenced by the IPCC Fourth Assessment Report: Climate Change 2007, Working Group 3. The original criteria cited in the report are *environmental effectiveness, cost-effectiveness, distributional effects, including equity, and institutional feasibility*. The criteria are commonly used to consider the value of climate and environment policy. The original criteria were slightly adapted to fit the objective of the present study (IPCC, 2007).

4.0 “ What practical, social, and political barriers and opportunities to scale up CDR are relevant to national policymaking?”

This chapter first gives an overview of the practical barriers and opportunities of some of the most mature CDR methods. Mature refers to CDR approaches that have been demonstrated to work and are ready to be deployed. To provide a general understanding of how the specific methods function they are presented with a description of the main technical, economic and biophysical factors that are relevant to consider upon implementation. Second, the section provides an overview of political and social barriers and opportunities found in the literature that are relevant to CDR policymaking. Here concepts are presented in subheaders and then discussed.

4.1 Practical barriers and opportunities of specific CDR solutions

In this section, the technological CDR approaches Direct Air capture with CCS (DACCS) and Bioenergy with CCS (BECCS), and their storage solutions will first be discussed. Subsequently, the nature-based approaches Biochar, Forestation and Wetland restoration will be discussed together with a general account of storage options for nature-based approaches.

4.1.1 Geological storage

The common trait of technological CDR methods is that the CO_2 captured is stored geologically. This means that after being captured, CO_2 can be stored geologically by being injected into underground saline or basalt rock formations, or in depleted oil and gas reservoirs. Geological CO_2 storage has been practised for 45 years and is considered a safe and mature storage opportunity (Global CCS Institute, 2018). Geological storage of CO_2 can be prone to leakage, however, if the storage sites are well-managed, the risk is seen as very low (Alcalde et al., 2018). Furthermore, many locations around the world have the right characteristics for CO_2 storage, and research shows that there is theoretically more than enough storage capacity around the world to store the amount of CO_2 needed to reach the international climate targets of limiting global warming to 1.5° or 2° C (Dooley, 2013)(Global CCS Institute, 2018).

However, the process of capture, transportation and storage represent at least two different stages in the value chain. Companies employing CCS are dependent on other companies delivering transportation and storage services. To attain CDR, the CO_2 captured from DACCS and BECCS must be stored geologically, which means that access to CO_2 transportation and storage infrastructure is critical for both technologies. Today, some limited actors provide CO_2 transportation and storage services, so even though there is a theoretical capacity, connecting the value chain from capture to storage can be seen as one of the main barriers to the implementation of technological CDR approaches (Haszeldine et al., 2018).

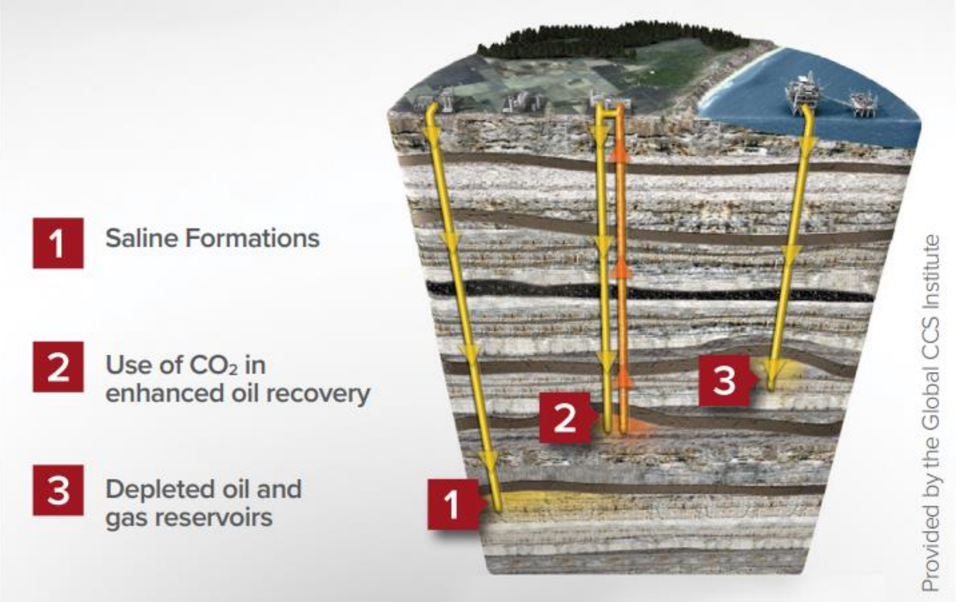

Figure 2: illustration of geological storage methods. Source: Global CCS institute (2018)

4.1.2 BECCS

Bio-energy with carbon capture and storage (BECCS) is the process of capturing and permanently storing biogenic emissions stemming from the industrial processing of biomass. (Geden & Schenuit, 2020). BECCS demands substantial amounts of biomass being grown to create CDR, thus the main limitation for large-scale deployment of BECCS is that it is land-intensive (Fuss et al., 2018). Furthermore, since the demand for biomass is expected to grow as the bio-economy materialises, the scale-up potential of the technologies using biomass is dependent on the future availability and price of biological material (Creutzig et al., 2019) (Zhang et al., 2019). Biofuels are one example of a solution where rollout has halted due to land-use conflict between fuels and food production (Honegger & Reiner, 2018). However, these potential drawbacks have a long timeframe and occur mainly when deployed at a large scale (Olsson et al., 2020).

The technology used for BECCS is CCS which is a quite mature technology that has been deployed at several fossil emission point sources. In 2020 26 commercial CCS facilities were operating globally (Möllersten & Naqvi, 2022). Several different CCS methods are being developed, with varying technology readiness, the most mature CCS technology is post-combustion capture where a chemical solvent is used (Möllersten & Naqvi, 2022). The ‘low hanging fruits’ are to apply CCS on existing biogenic emission point sources where biomass is already used in production and the subsequent emissions are released to the atmosphere (Möllersten & Naqvi, 2022). Currently, there are several BECCS projects underway in Europe on waste-to-energy facilities. Pulp and paper mills and bioethanol production facilities are also proposed as suitable candidates for BECCS (Olsson et al., 2020). To date, there is only one large-scale BECCS plant operating globally, located in Illinois in the United States (Tamme & Beck, 2021).

Biomass used for BECCS must be sourced sustainably, if it is sourced unsustainably there is a risk that emissions from production might cancel out the removals when used for bioenergy. If biomass is harvested without assuring new biomass reoccurs, the process does not lead to the removal of CO_2 from the atmosphere. The most suitable biomaterial to use for BECCS is household and industrial wastes, agricultural and forest residues, or energy crops that are grown to be used for BECCS. It should be noted that producing energy crops requires water and fertiliser which can have negative effects on food production and biodiversity if BECCS is to be deployed on a large scale (Geden & Schenuit, 2020).

Further, successful BECCS is dependent on integrating the whole value chain from capture to storage. The application of BECCS requires that the location of the plant, which needs to be near biomass input, must also be connected to transportation and storage infrastructure which will have effects on both feasibility and costs (Fuss et al., 2018). However, the technological and biophysical barriers to near and medium-term deployment are likely not prohibitive to deployment (Olsson et al., 2020). The most pressing challenge today is the high investment and operational costs that require policy incentives, which have been the main barrier to the deployment of CCS to date.

Current cost estimates for BECCS vary greatly due to geological variations in the availability of biomass and access to storage infrastructure. Recent global estimates project costs between 15 - 400 US dollars per ton of CO_2 removed (Möllersten & Naqvi, 2022). However, a cost analysis of BECCS in Sweden, which is relevant due to similar conditions to that of Norway, estimates capture costs between 47-60 Euros, and 20-40 Euros for transportation and storage. Moreover, the cost relating to the technology part of BECCS, CCS is expected to decrease as the total of installations increases (Möllersten & Naqvi, 2022). In the long-term costs of BECCS are expected to increase in line with the demand for biomass.

4.1.3 DACCS

Several different technologies are being investigated to capture CO_2 directly from the air. The most mature direct air capture (DAC) technologies, notably still early in the commercial stage, can be divided into two groups, those that use water solutions DAC1, and those that use solid sorbents DAC2 (Realmonte et al., 2019). The most important difference between the two technologies is the temperature required in the process of extracting CO_2 from the air. DAC1 is the most advanced technology of the two and requires temperatures above 800 degrees, which has made natural gas the most used source of energy. DAC2 is still in the innovation and demonstration phase but requires lower temperatures, around 85-120 degrees which makes waste heat a possible energy supplier (Realmonte et al., 2019). Regardless, both can use renewable energy in production (IEA, 2021). An additional advantage of DAC2 is that the design is modular which makes it suitable for mass production and probable cost reductions (Realmonte et al., 2019).

The pressing challenge for the deployment of DACCS is the technology's high energy demand. Since the CO_2 is captured directly from the air, CO_2 concentrations are relatively low compared to point source capture with CCS, and the large quantity of airflow necessitates high energy consumption (Möllersten & Naqvi, 2022). An analysis of DACCS' feasibility at scale calculated that capturing 30 Gt CO_2 per year with DACCS will require around 12-20% of the global total energy supply (Chatterjee & Huang, 2020). However, the projection is based on the current technologies' energy consumption and the future prediction of large-scale deployment.

Although the limited use of water and land required for DACCS compared to BECCS and afforestation is considered a benefit of the technology (IEA, 2021), biophysical constraints must also be taken into consideration. The facilities are estimated to use 1.5 km^2 per million ton captured. DACCS also uses some fresh water in its production so the location of the plant will be dependent on access to fresh water without having negative consequences on the local water supply (Möllersten & Naqvi, 2022). If DACCS plants are placed near geological storage, where there is access to renewable energy and water supply the main limitation to date is also costs and policy incentives. There are currently 19 operational DAC plants worldwide, these are small-scale facilities that mostly deliver the CO_2 for further use, which does count as CDR. The first large-scale CDR DACCS plant is being established in the US by the company Carbon Engineering (IEA, 2021).

Cost estimates for DACCS range widely from 100 - 1000 US dollars per ton removed, depending on geographically determined factors such as access to energy and transportation and storage (IEA, 2021). However, the costs are projected to decrease rapidly if commercialisation happens within the current century, optimistic estimates project costs to possibly reach 32 - 54 Euro per ton of O_2 removed in 2050, however, future costs are highly uncertain (Fasihi et al., 2019).

The analysis of practical barriers and opportunities for technological CDR approaches implied that costs of BECCS will decline in the short term but then increase when demand for land and biomass increases in the long term. On the contrary, DACCS has high costs in the near term but if the technology is taken into use, the technological learning is expected to drive down costs substantially. It also showed that many of the barriers identified are present on an aggregated level. If biomass can be sourced sustainably for BECCS, and renewable energy for DACCS, the main barrier to national deployment today are high investment and operational costs. The common barrier to date is that both technologies are dependent on transportation and storage infrastructure.

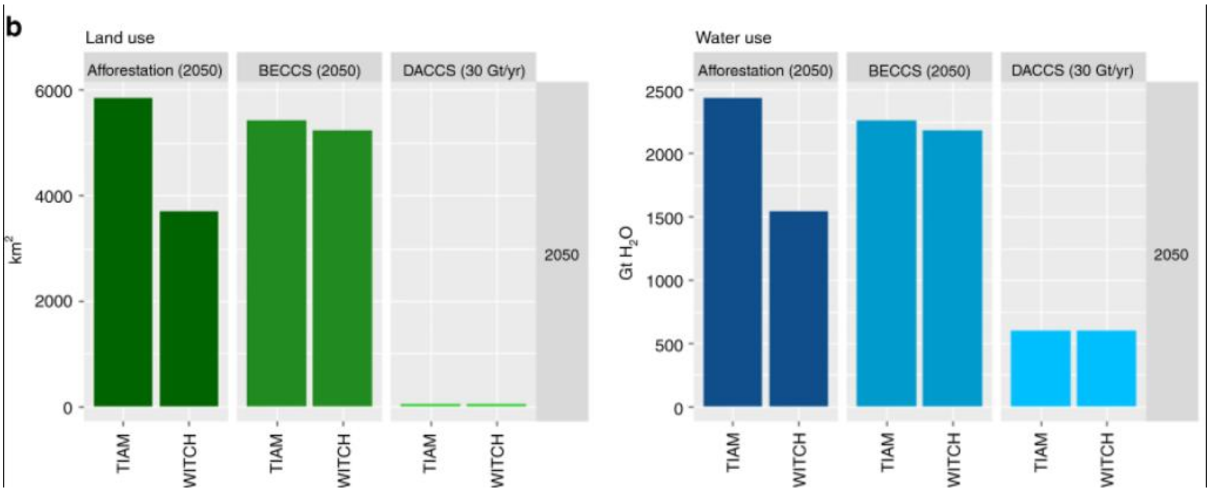

Figure 3: Land and water use estimates of different CDR approaches to capture 30 Gt of CO2 in different IAMs. Source: Realmonte et al. (2019)

4.1.4 Nature-based CDR & storage durability

The basic principle of CDR is that CO_2 is stored durably (Honegger et al., 2021). However, a great general limitation of nature-based CDR is that the carbon storage durability is largely uncertain and varies greatly according to individual traits of the respective ecosystems, such as soil quality and species type (Brander et al., 2021). Furthermore, carbon stored in nature-based carbon sinks faces the risk of reversal due to natural and human exogenous factors. Changing priorities for the area used for nature-based CDR such as logging, construction or agriculture can lead to CO_2 being released back into the air. Natural occurrences - that will become more frequent when the global mean temperature rises – such as drought, storms and pests are also a threat to nature-based CO_2 storage (Brander et al., 2021) (Geden & Schenuit, 2020). Additionally, carbon uptake in ecosystems does not grow indefinitely, they reach a carbon equilibrium. Thus if the nature-based solutions are not replaced with additional measures, the storage durability is temporary (The Royal Society, 2018). Temporary solutions can safeguard against temperature overshoot, but they do not assure an indefinite contribution to temperature stabilisation (Brander et al., 2021)(Matthews et al., 2022). Eco-systems store large quantities of carbon, but that carbon can easily be released back into the atmosphere, a trait that is important to consider when making policy (The Royal Society, 2018).

4.1.5 Biochar

The primary method for producing Biochar is by burning biomass in temperatures between 300-800 degrees and without oxygen, a process called pyrolysis, which leaves the biomass as a solid substance that consists mostly of CO_2. Other methods to make biochar are hydrothermal carbonisation and biomass gasification (Möllersten & Naqvi, 2022). Even though Biochar is listed here as a nature-based solution, it can be seen as a hybrid since it needs technology to be converted. The biomass used to produce biochar can come from a large variety of feedstock, however dedicated energy crops and bio-waste will have the best climate effect. Like BECCS, a restricting factor for Biochar at scale is the land required to produce the biomass (Fuss et al., 2018).

Biochar creates CDR if it is buried in the soil. In addition to having carbon storage characteristics, the advantage of biochar is that it has co-benefits on soil fertility and can thus be used as fertiliser in the agricultural sector. Other co-benefits of biochar are that it can increase yield productivity and have positive effects on the soil's ability to hold water and nutrients. A disadvantage is that adding a lot of biochar in an area can darken the soil surface which decreases the albedo effect - the surface's ability to reflect light - which has negative climate effects (Fuss et al., 2018).

The storage durability of biochar is estimated to be medium-term (Jeffery et al., 2020). Variabilities in the production methods of the biochar and the soil where it is stored affect the durability from a few decades to centuries (Fuss et al., 2018). The predicted cost of biochar is also highly uncertain and spans from 18 – 166 US dollars per ton CO_2removed (The Royal Society, 2018). Policy incentives due to high costs and access to sustainable biomass are today the biggest barrier to deployment.

4.1.6 Afforestation, reforestation, and forest management

Afforestation and reforestation are the most known and practised forms of CDR. As trees grow, they absorb CO_2 from the atmosphere which is stored in the biomass and soil. Afforestation is planting trees in new areas whereas reforestation is planting trees in areas previously deforested. The two practices are hereafter referred to collectively as forestation (The Royal Society, 2018). Enhanced forest management can increase the net uptake of the forest by thinning forests and improving species rotation (The Royal Society, 2018). A tree does not grow infinitely, it matures and eventually decays and falls dead. When it falls dead some of the CO2 is bound in the soil, but most is realised again into the air. Instead, when trees mature, they can be harvested and used for bio-products that can substitute fossil-based products, if the bio-products in long-lived, such as wood for construction, it means that the carbon will be stored longer. Wood can also be used for BECCS or to produce biochar (The Royal Society, 2018).

The most limiting factor for large-scale forestation is its large land and water use which can come in conflict with other social and economic interests (Geden & Schenuit, 2020). However, deforestation is still a problem in most countries. Consequently, protecting remaining forests, and returning previously deforested areas to their natural state by afforesting, and enhancing current forestry practices are key actions to secure and enhance carbon sequestration. An advantage of forestation is that planting trees is a low resource demanding practice. However, since there isn't a carbon market, sequestration does not yield income for landowners, many may choose other agricultural practices over forestation due to economic interests. Thus, policy incentives are key to deployment (The Royal Society, 2018).

It is often taken for granted that forestation has positive side-effects on ecosystems, however, the specific planting practice and location determines whether forestation has negative or positive effects. Substituting a natural habitat with one type of fast-growing tree can have large detrimental effects on ecosystems on the converted land, on the other hand, planting trees with a variety of tree species on degraded land can have severe positive impacts on biodiversity and ecosystems. Finding suitable locations, and taking the local environment into account is, therefore, a necessary prerequisite for sustainable forestation. Also, practices such as agroforestry which combine agriculture and forestry to enhance co-benefits enable food production and tree planting to be combined in a sustainable manner (The Royal Society, 2018).

4.1.7 Wetland, peatland, and coastal habitat restoration

Wetlands which include peatlands and coastal habitats are one of the largest terrestrial carbon sinks globally and important ecosystem habitats (Möllersten & Naqvi, 2022). However, wetlands are frequently exploited, drained and degraded due to human activity, consequently releasing a lot of CO_2 into the atmosphere and simultaneously contributing to the loss of biodiversity (The Royal Society, 2018). Habitat restoration is the practice of restoring or constructing new such systems and is an important CDR practice because wetlands inhabit the highest carbon stock per unit of area of all ecosystems (Griscom et al., 2017). Re-wetting drained wetland and restoring previous vegetation can reverse the effect and re-establish CO_2 capacity, however, increased methane emissions that follow from re-wetting can offset some of the recurring sequestration (Möllersten & Naqvi, 2022). Wetlands are often drained for agriculture and food-production purposes, so restoration can also come into conflict with other land uses (Möllersten & Naqvi, 2022).

A great prospect with the practice is as mentioned the co-benefits between ecosystems and carbon storage. Additionally, there is much knowledge on wetlands since humans have been managing these for a long time, and many restoration projects are already implemented across Europe, which has generated significant learning (Möllersten & Naqvi, 2022) (The Royal Society, 2018). Restoration of wetlands can be a cost-effective CDR approach, but costs differ widely from project to project. The Swedish Environmental Agency estimates the cost to be around 10 dollars per ton of CO_2 removed, which includes estimated increases in methane release and decreases in CO_2 emissions (Möllersten & Naqvi, 2022, p. 41).

The analysis of practical barriers and opportunities for mature nature-based approaches included in this research also showed that many of the obstacles present themselves when the approaches are deployed at a large scale. It also demonstrated that it is important to take other environmental effects, not only CO_2 sequestration, into consideration when planning measures.

4.2 Social and political limitations and prospects for large scale CDR deployment

There are not only bio-physical and techno-economic factors that impact the viability of CDR, social and political aspects are also crucial factors to implementation. This section will discuss the most important social and political factors that are relevant to informing policymakers. The following section will discuss mitigation deterrence, public perception, common but differentiated CDR response, financing CDR with offsets, accounting: biogenic versus fossil emissions, and lastly the effect of CDR on existing ecosystem carbon sinks.

4.2.1 (Overcoming) CDR as mitigation deterrence

Despite the IPCC’s view of CDRs as a strictly necessary tool in the fight to stop global warming, CDR is not uncontroversial (Lundberg & Fridahl, 2022). Opponents to the reliance on the technology argue that CDR is a distraction in the climate debate, where the promise of future cost-optimal climate technology that is untested on large-scale delays or substitutes effective emission reductions today, consequently extending the carbon budget (Haszeldine, 2016). As such the 'fossil age' is prolonged by the possibility for companies and politicians to offset their current emissions with future CDR (Waller et al., 2020).

> *"If mitigation is understood as planned at-source reductions in greenhouse gas emissions, then mitigation deterrence can be defined as the prospect of reduced or delayed at-source emissions reductions resulting from the introduction or consideration of another climate intervention"* (Markusson et al., 2018)

As already mentioned, climate modelling and scenarios that are consistent with reaching 1.5° and even 2 °C use CDR technologies on a very large scale, assuming it is technically, economically, and socially feasible (Anderson & Peters, 2016). The IPCC, in their reports, gives a wide array of possible mitigation pathways. Those that reach the climate goals either demand rapid emission reductions - far greater than what the national pledges currently represent - or large-scale deployment of CDR.

While researchers often emphasise that the technology needs to be used as an additional tool to traditional mitigation; emission reductions, McLaren et al., (2019) suggest that the wide use of CDR in IAMs - that informs policymakers about cost-efficient mitigation - assuming certain cost reductions without knowing the true potential, have already delayed mitigation. This is because the use of CDR enables delayed mitigation, and for policymakers "The promise of future and cost-optimal negative-emission technologies is more politically appealing than the prospect of developing policies to deliver rapid and deep mitigation now."(Anderson & Peters, 2016).

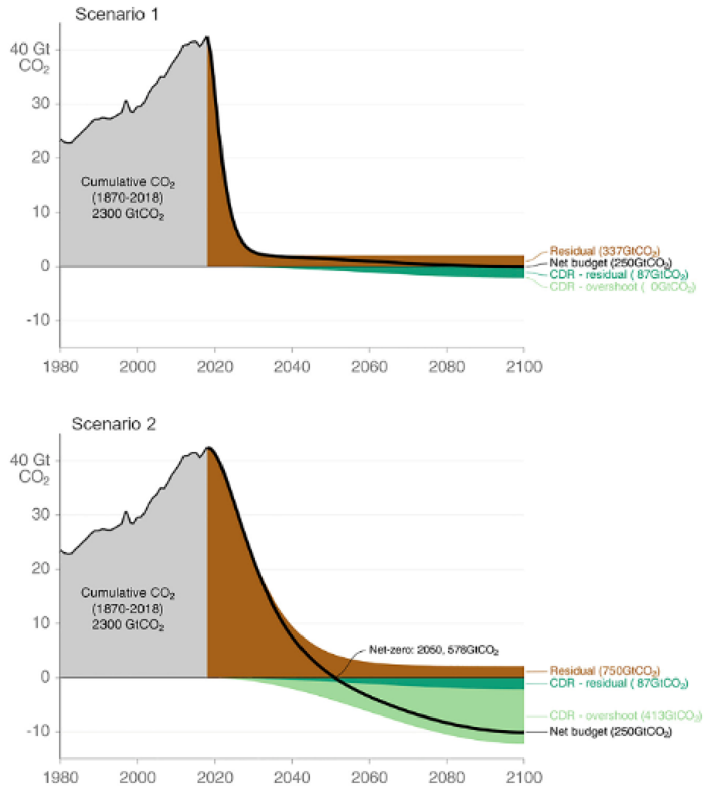

Figure 1. Historical Emissions and Stylized Pathways that Emit Less Than 250 Gt CO_2 between 2019 and 2100 to Limit the Temperature Increase to 1.5°C in 2100

Scenario 1: negative emissions offset residual (positive) emissions, resulting in little CDR and drastic and immediate emission reductions.

Scenario 2: greater (positive) emissions result in larger CDR and higher overshoot before the temperature increase declines to 1.3°C–1.4°C in 2100, still with drastic CO_2 emission reductions in the next two decades.

Both scenarios reach 1.3°C–1.4°C in 2100, but temperature diverges beforehand. Data sources: historical emissions from the Global Carbon Project; scenarios based on stylized functions with cumulative emissions consistent with scenarios from the IPCC SR1.5 scenario database.

Figure 4: the increasing need for CDR dependent on the pace of emission reductions. Source: Fuss et al. (2020)

Given the extensive use of CDR in climate modelling, where many scenarios assessed by the IPCC depend on large scale deployment by 2030, one could assume that political action to support the technologies would materialise, however, CDR policy is absent in almost all countries' policy debates (Anderson & Peters, 2016; Schenuit et al., 2021). The large discrepancy between the use of CDR in models and actual deployment and policy efforts in the real world increases the chances of CDR deterring mitigation becomes true. Given only one large-scale BECCS facility exists, and only one DACCS plant is underway, these concerns are reasonable.

Regardless, to reach the international climate targets the world must use all mitigation options available, also CDR (Honegger & Reiner, 2018). Nevertheless, it requires a policy debate on CDR's role as a climate solution and subsequent careful policy design (McLaren et al., 2019). Even if the world would stop emitting CO_2 as quickly as practically possible, there would still be enough CO_2 already emitted to the atmosphere to face dangerous climate impacts (Morrow et al., 2020). Rather than denying the technologies that could play an important role in limiting global warming, it is necessary to keep two thoughts at the same time to assure CDR deployment. Emphasising that emission reductions must be at the centre of the strategy to reach the climate goals; “mitigation actions should be performed on the premise that CDR will not deliver what is projected” (Anderson & Peters, 2016). Moreover, creating policy enablers to realise CDR as an additional tool can reduce the climate risks by reducing atmospheric CO_2 concentrations.

To avoid CDR undermining other policy interventions, and to assure that CDR contributes to raising ambitions, McLaren et al., (2019) propose to separate targets and accounting for emission reductions and CDR. The concept of net-zero has become a norm in climate policy-making, without specification and definitions of what net-zero entails, continued and prolonged use of fossil fuels can be enabled by CDR. Separating national targets would ensure necessary emission reduction while simultaneously contributing to defining CDR’s role in mitigation policy and avoiding substituting reductions for removals.

4.2.2 Public perception

It is not only technical, economic, and political barriers to the viability of CDR, societal opposition may support or constrain implementation. Additionally, it is not merely the material properties of a technology that determines its image, how the technology is presented and perceived in context to other societal factors influences perceptions (The Royal Society, 2018).

Studies suggest that there is a general lack of public awareness about BECCS and DACCS that might undermine the implementation of the technology (Waller et al., 2020), and that how technology is framed highly impacts how the respective technology is viewed (Cox et al., 2020). Research on public perception of CDR in the UK and US suggested that technological solutions were not necessarily seen as commensurable with a sustainable and decarbonized future, and concerns over risks associated with geological storage were an emerging theme among participants in the research (Cox et al., 2020). However, CDR is a relatively new concept among the general population and there is no extensive research on public responses yet. Nonetheless, research on CCS - that is relevant to technological CDR - can give some valuable insights about failures and successes (Honegger & Reiner, 2018).

Despite the development of CCS stalling for a while, CCS is getting some new momentum with a growing number of projects being realised, from under 10 operational facilities in 2010 to 27 in 2022 (Global CCS Institute, 2021), at the same time as international law is improving (Merk et al., 2022).

Generally, a key obstacle to the development of CCS technology in Europe is that there has been low awareness of CCS among the public (Merk et al., 2022). In Germany, CCS has historically received strong opposition. Onshore storage and the connection between CCS and the fossil industry have been key aspects that led to public opposition (Honegger & Reiner, 2018). CCS in Germany was first introduced as an opportunity to abate emissions from coal plants, but recent developments on the debate around which emissions to avoid have created more acceptability. The Greens in Germany, who are highly opposed to the continued use of coal with CCS, are now more open to the use of CCS on process-related emissions from the industry (Fischer, 2015). By contrast, there has been relatively high support for CCS in Norway, which can be related to, among other reasons, that the storage facilities are offshore which limits the ‘not in my backyard’ effect (Merk et al., 2022). Additionally, research shows that countries producing oil and gas are more politically committed to CCS, whereas Norway is the country that has hathe d highest funding for CCS RD&D per capita (Tjernshaugen, 2008).

While some CDRs use CCS technology, the concept of CDR is fundamentally different in that it seeks to remove CO2 from the atmosphere with a diverse array of methods. CCS on the other hand is a solution to abate fossil fuel emissions from point sources, a trait that might depict a higher chance of the technology being rendered as mitigation deterrence due to its association with the fossil industry.

It should be noted that the mentioned factors alone are not the only reason for the slow deployment of CCS internationally. Cost overruns and technological issues that have delayed projects are also causing protests against certain projects (Honegger & Reiner, 2018). A general lesson from implementing technology is that the failure of early projects can tarnish the reputation of a specific technology, and slow down deployment (Honegger & Reiner, 2018).

Nature-based solutions are more prone to be favoured by the public since what is labelled *natural* often is preferred over actions or policies that are seen as *artificial* or *unnatural*

(Bellamy & Osaka, 2019). This is true in the UK, where a study on public perception concluded that the majority of the public preferred nature-based solutions over technological ones (Schenuit et al., 2021). However, it is not given that the nature-based solutions are socially, environmentally, and economically more beneficial. Large-scale single species planting can have large negative effects on ecosystem services. Additionally, the line between what is categorised as natural and technical is quite blurry, take biochar for example - that requires both biomass and technology to be produced - is classified as a nature-based solution, but BECCS on the contrary is classified as a technical solution, even though the main elements are the same (Bellamy & Osaka, 2019). Deeming solutions as natural or unnatural might distort the picture of the potential of the different solutions, favouring and disfavouring some unjustifiably. Further research on public perception is thus needed, with a focus on the different CDR technologies because a full understanding of the public perception of CDR is lacking (Cox et al., 2020).

The political framing of CDRs will influence public perception (Nemet et al., 2018), therefore, careful policy planning with clear communication of the reason and purpose of deployment can contribute to avoiding CDR technologies from being framed unfavourably. Focusing on a gradual rollout, further research on CDR technologies' limitations and prospects, and emphasise the limited contribution of CDR technologies in reaching the climate targets can contribute to raising awareness and promote a fruitful discussion that goes beyond CDR being viewed as mitigation deterrence (Honegger & Reiner, 2018).

4.2.3 Common but differentiated CDR response

CDR can serve two main mitigation purposes. In the short-term CDR can offset the hard-to-abate emissions such as cement and steel production, aviation, waste incineration and long-distance transport before better solutions are applicable. In the long-term CDR can also be used to offset the emissions so far seemingly impossible-to-abate such as agriculture, and potential residual emissions. However, according to most of the climate scenarios that reach the climate goals, CDR must also be used to remove some of the CO_2 already emitted to the atmosphere and enable net-negative emissions globally (Geden & Peters, 2017). The removal of already emitted CO_2 creates broader international policy implications. Because questions such as ”which countries are responsible for removing CO_2 historically emitted to the atmosphere?”, “Which countries are going to start CDR first?” And “which countries will and should deliver the bulk of the CDR?” arises (Geden & Peters, 2017). CDR efforts will not be distributed equally across the globe, as most CDR options are more expensive than other mitigation options today (Honegger, Burns, et al., 2021).

The success of the Paris Agreement hinged on the equity premise that wealthier and more developed countries have more responsibility than lesser developed and affluent countries. Which countries should take the lead in developing CDR can be seen in context with the ‘common but differentiated responsibilities’ principle set out by the Paris agreement (Fuss & Johnsson, 2021). In the literature on CDR, it is emphasised that it is expected that countries with resources and high emissions per GDP start to develop CDR technology to drive down costs so that CDR eventually can balance out emissions also in countries that probably will reach net zero after 2050 (Pozo et al., 2020) (Honegger & Reiner, 2018). In time, CDR costs will be reduced, at least for some methods, and costs of emission reductions will rise when only the most expensive reductions remain. It is thus necessary that countries with capabilities take a leadership role to develop the technology to enable the scale-up required.

4.2.4 Financing CDR by establishing a credible voluntary market

Voluntary carbon offsetting has long been a popular practice for companies and countries to meet their climate ambitions (Jeffery et al., 2020). Carbon offsetting can be defined as a “payment to receive credit for a certified unit of emission reduction or removal carried out by another actor.” (Allen et al., 2020). Introducing CDR to the voluntary offset market has been proposed as a measure to provide the necessary funding to scale up deployment (McLaren et al., 2019), and influential companies like Microsoft have announced that they want to offset their *historic* emissions by buying technological CDR-offsets (Joppa et al., 2021).

Private and public cross-border financing could be an important financial enabler to the deployment of CDR, but if used inappropriately market-based instruments could threaten the efficacy of global mitigation action (Michaelowa et al., 2019). To enable international trade, a credible carbon market must be established. This involves setting consistent universal standards for measuring, verifying, and accounting (Joppa et al., 2021).

Nature-based and technological approaches to CDR are due to the inherent risk of reversal and uncertainty and inconsistency of the durability of CO_2 storage, as discussed above, are not equal entities and should therefore not be valued as the same. In the current market, both approaches are treated the same, encouraging companies to buy the cheapest credits which often are the ones with the highest risk of reversal or lowest climate benefit (Joppa et al., 2021).

There are suggested alternative approaches to safeguard against the risk of CO_2 reversal from the deployment of non-permanent solutions. Such as creating temporary credits where credits have an expiry date and buyers must acquire new credits to expand the offset or creating a buffer account where more CO_2 is stored than what is acquired by the buyer in case of reversal(Brander et al., 2021). Alternatively, to offset ongoing emissions, it is proposed that entities buying credits could claim to provide financial support to sustainable projects without claiming neutrality, a concept called climate financing. However, the latter proposal might decrease the willingness to buy credits (Jeffery et al., 2020, p., 17). Regardless, allowing nature-based approaches to offset emissions requires international efforts to enhance the certification of high-quality nature-based removals (Honegger, Poralla, et al., 2021). Without such safeguards, nature-based solutions risk having adverse climate impacts when used to offset fossil emissions.

Offsetting through technological CDR with permanent CO_2 storage is a more credible approach (Allen et al., 2020), but there are concerns that offsetting, in general, will delay decarbonisation because it distorts incentives to reduce emissions if it is possible to buy credits (Jeffery et al., 2020). However, on the road to full decarbonization, actors could finance CDR to compensate for the not yet abated emissions. To ensure that CDR does not deter emission reductions, companies and countries could set a zero or very low emission target and a separate target for CDR (which could include historic emissions). To ensure that the necessary incentives to reduce own emissions and increasing removals could occur dually by using the separation approach as proposed by McLaren et al. (2019). This involves creating a framework to operationalize net-zero targets and could enable necessary action to prepare for becoming global net-negative in 2050 (Jeffery et al., 2020, p., 20).

Creating a market for CDR will require robust, science-based methods for monitoring, reporting and verification of CDR measures. These can initially be developed and implemented nationally while awaiting common standards but to facilitate international trade of CDR - to enable countries and private actors to reach net-zero in time in a credible way - requires international standards. Hence, policymakers need to promote international action to settle such standards (Tamme & Beck, 2021)(The Royal Society, 2018)(Fuss et al., 2014).

4.2.5 Accounting: biogenic versus fossil CO_2

Guidelines from the UNFCCC require parties to the convention (countries) to report emissions derived from human activity; emissions from the use of fossil fuels and land-use change. The latter refers to when land, previously inhabited by natural landscapes such as forests, is converted to be used for other human activities such as building or agriculture, which often leads to emissions of GHG. However, the use of biogenic material for energy, bioenergy, is defined to be a part of the 'natural carbon cycle', as described in the background, and thus left out of national GHG reporting. Even though some land-use change emissions are regulated, the emissions from burning biomass at point sources are not required to be accounted for in the national GHG inventories. Biogenic and fossil CO_2 have the same effect on the climate per unit emitted, but if biomass is sourced sustainably, new units of biomass that grow up offset the used one. Consequently, since biogenic emissions have not been accounted for there has been little incentive to capture and store them, which has been the main barrier to the implementation of BECCS (The Royal Society, 2018).

During COP 26 in Glasgow, the accounting rules for the removal and permanent storage of biogenic emissions were changed, countries can now count removed and permanently stored biogenic CO_2 into their national GHG inventory reports. An important note here is that the release of biogenic emissions is still not accounted into budgets because it encourages the use of bioenergy instead of fossil fuels, it is only the removal of biogenic emissions that can now be included (Miljødirektoratet, 2022). The alteration of the accounting framework creates incentives for governments to remove biogenic CO_2 as a measure to meet their climate obligations.

4.2.6 The effect of CO_2 removal on the natural carbon sinks

It is commonly believed that one ton of CO_2 emitted represents the same as one ton removed, but recent research suggests that this is not necessarily always true (Zickfeld et al., 2021). When the atmospheric CO_2 concentration increased due to human activity, so did the uptake of CO_2 by the natural carbon sinks. Furthermore, when carbon is to be removed from the atmosphere and the accumulated atmospheric CO_2 concentrations start to decrease, land and ocean sinks will release some CO_2, consequently creating an asymmetry between removals and emissions. This means that offsetting one ton of CO_2 with CDR might not have the same effect as avoiding one ton of CO_2 emission (Zickfeld et al., 2021). However, this effect will start to occur when the accumulated CO_2 levels start to decrease, that is when the world reaches net negative CO_2 emissions. Today and in the near future emissions are still rising, so the effect can become an issue when emissions are severely reduced and when CDR is deployed at scale to enable net negative emissions. Currently, it seems plausible to count one ton removed as the same as one ton emitted. However, in the future, safeguarding against this effect might become necessary, by for example obliging actors to remove more than one ton to offset one emitted.

The previous chapter showed that there are various political and social complexities involved that can affect the realisation of CDR. Most noteworthy to national policymaking is that if separated targets are not established on the national level, there is a risk that CDR contributes to slowing down decarbonisation, which might already have been the case. Additionally, how CDR measures are presented and framed can determine whether it is taken in use or not. Independently, public perception can be decisive for implementation.

5.0 “What are the main elements of the CDR regime in Norway??

This chapter will first investigate the history of CCS in Norway followed by the latest policy developments related to technological CDR. Afterwards, it will analyse the history of nature-based CDR, in addition to its latest developments.

5.1 History of CCS in Norway

While this thesis’ focus is on CDR, the history and development of CCS are relevant to this study since CCS is an integral part of technological CDR approaches, hence sharing similar barriers and opportunities (Fuss & Johnsson, 2021). So to understand how BECCS and DACCS can be scaled up to become a part of the mitigation strategy in Norway, this following section will go through the most overarching and outstanding dynamics and reasons for how CCS emerged in Norway, followed by the most recent policy developments.

How CCS entered the Norwegian socio-technical regime

The world’s first CCS plant was deployed at the oil field Sleipner in Norway already in 1996. The plant captures around 1 Mt CO_2 a year from oil and gas production that is later injected one kilometre under the seabed in a saltwater reservoir (van Alphen et al., 2009). CCS was also later deployed at the liquified natural gas production facility “Snøhvit” in 2004, which captures and stores around 0,7 Mt CO_2 a year. In an analysis of the Norwegian CCS innovation system Van Alphen et al., (2009) ascribes the carbon tax directed at the offshore petroleum industry imposed in 1992 (around €40 per t/CO_2) as the triggering cause for employing CCS at Sleipner and Snøhvit. The (partly) state-owned oil and gas company Statoil, today Equinor supposedly employed CCS to avoid the cost of paying the tax (van Alphen et al., 2009) (Røttereng, 2017). The oil and gas industry which had expertise and resources to develop the technology was an important factor for the technology to develop to deployment and since CCS is not a competing technology but rather a supplementary tool to develop the industry, CCS can be seen as a symbiotic technology.

On the landscape level, the increased focus on climate and environment internationally during the 1980s is a more underlying cause for early CCS development in Norway

(Tjernshaugen, 2011). Gro Harlem Brundtland, the prime minister in Norway at the time, was also appointed leader of the UN World Commission on Environment and Development, later called the ‘Brundtland Commission’ who published the report “Our Common Future” and coined the term sustainable development. Brundtland was engaged in the environment debate and brought it to the forefront of Norwegian politics at a time when Norway's oil and gas industry was rapidly expanding (Lahn et al., 2019). The paradox of being one of the most active leaders in the international climate regime and having rising emissions from the petroleum industry is attributed to be an important driver for CCS initiatives (Lahn et al., 2019)(Tjernshaugen, 2011, p. 227).

The environmental movement in Norway is identified to be an important “policy entrepreneurs” who legitimised and advocated for CCS implementation in Norwegian politics. The environmental non-governmental organisation (ENGO) the Bellona Foundation has been a vocal advocate for deployment since CCS entered the political scene as a climate solution. The ENGO Zero Emission Resource Organisation (ZERO) later also became an important contributor to lobbying for CCS projects. Greenpeace, which has been a key actor opposed to the use of CCS internationally has been “weakly represented in Norway”, so the resistance to the technology in the early phases was limited in comparison to other countries (Tjernshaugen, 2011). Norway has historically had one of the largest funding programs for CCS relative to its GDP, which can be linked to the petroleum industry and the issue of reconciling extracting fossil fuels with environmental politics (Tjernshaugen, 2008).

During the 1990s CCS became more controversial, the technology was expensive and deemed by many as an unnecessary and expensive mitigation option and halted further development (Tjernshaugen, 2011). This was in a post-Kyoto Protocol time, where emission trading was a cheaper option to cut emissions (Lahn et al., 2019). However, CCS got new wind under its wings in the late 90s due to a national debate on whether to include gas-fired power plants in the Norwegian energy system. A broad coalition did not want to establish a gas-fired power plant since the Norwegian energy system had been based on hydropower and was 100% renewable. The debate made the policy entrepreneurs to propel CCS to the centre stage of Norwegian politics and propose CCS as a compromise (Tjernshaugen, 2011) (Lahn et al., 2019). Even though there was broad public and political support for CCS it did not materialise together with the gas power plant as the cost-effectiveness approach in Norwegian climate policy mandated other initiatives (Tjernshaugen, 2011) (Lahn et al., 2019).

Regardless of the political and civil support for CCS, Snøhvit and Sleipner remain today as the only operating industrial sites where CO_2 is captured and stored (van Alphen, Hekkert, et al., 2009). After the gas controversy, the focus on CCS shifted from being a strategy to fulfil national climate targets to contribute to global development through funding of CCS RD&D (Røttereng, 2017). Up until today there has been varying but continued support through different governments for research and development. The CLIMT program which is the national program for CCS RD&D was established in 2005 and has since funded national and international CCS technology development (Stangeland et al., 2021). The Mongstad Technology Test Centre (TCM) was established in 2012 and is the world's largest facility for testing technologies for CO_2 capture (Regjeringen, 2019). The Norwegian Research Council is the main funder of the Norwegian CCS centre who researches the role of CCS in reaching the climate goals of the Paris Agreement (Nordic Council of Ministers, 2021, p. 34).

5.2 Latest developments, technological CDR in Norway

In January 2020 Norwegian state agencies published “Klimakur 2030”, an analysis commissioned by the government, which quantifies the emission trends in the sectors not covered by the European Union Emission Trading System (EU ETS) and associated potential measures that the government can use to reduce the respective emissions (Miljødirektoratet et al., 2020). An important note is that when Klimakur was published, the capture and storage of biogenic CO_2 could not be counted off in national emission accounting according to international emission reporting guidelines, consequently, the removal of bio-CO_2 with CCS is thus not proposed as a separate measure in Klimakur (Miljødirektoratet et al., 2020, p., 32). The report suggests implementing CCS on three national waste incineration plants (Oslo Fortum Varme, BIR in Bergen and Heimdal in Trondheim) to avoid the respective facilities’ fossil emissions, and the amount of bio-CO2 is not included in the analysis emission budget. It is mentioned in ‘Klimakur’ that CCS could be a possibility in facilities with large biogenic CO_2 emissions such as biogas and biofuels production if the regulatory barriers are changed (Miljødirektoratet et al., 2020., 301).

Longship and the realisation of two CCS plants

Later in 2020, the Norwegian government announced the project ‘Longship’, which is a full-scale carbon capture, transportation, and storage project. The government announced that they would finance CCS at “Norcem”, a cement factory where 400.000-ton CO_2 will be captured and permanently stored annually starting in 2024. The government also pledged to partly finance CO_2 capture at the "Fortum Oslo Varme" which is the capital's waste incineration plant partly owned by the Oslo municipality and the company Fortum, on the condition that they collected the rest of the necessary funding elsewhere, through programs such as the EU innovation fund (Regjeringen, 2020).

The transportation and storage project 'Northern Lights' consists of a collaboration between the oil and gas companies Shell, Equinor and Total, who will transport CO_2 by ship, and inject the captured CO_2 into geological formations several kilometres under the seabed in the North Sea. The government announced that they would support the project with funding to cover initial capital investments and 10 years of operational expenses (Tamme & Beck, 2021), where the total funding is estimated to be 16.8 billion NOK (Regjeringen, 2020). Northern Lights have ambitions beyond the Norwegian borders, the project aims to create an open-access infrastructure to receive captured and liquified CO_2 at ports across Europe for transportation and storage in the North Sea. The project will start operations in 2024.

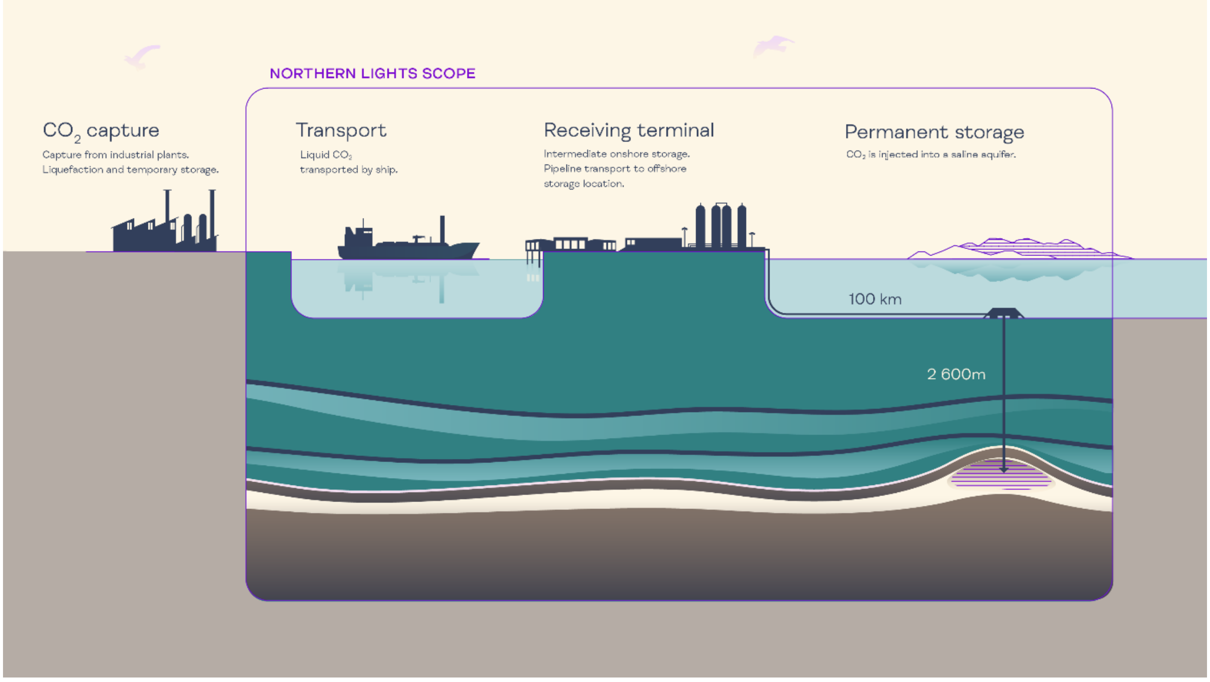

Figure 5: Illustration of the transportation and storage project. Source: Northern Lights

Fortum Oslo Varme, which got conditional funding from the government, did not get funding from the EU innovation fund in the 2021 round. However, in March 2022 the municipality announced that Fortum formed an agreement with three companies to buy their 50% ownership interests and further invest 6 billion NOK to realise CCS. This agreement is in partnership with the municipality which will transfer its shares to the three buyers and provide a shareholder loan to cover the municipality's project expenditures (Oslo kommune, 2022).

The waste incarnation plant is the biggest single emitter in the city of Oslo and accounts for 17% of the city’s emissions (Oslo kommune, 2022). Since around half of the emissions come from biogenic sources, such as food waste, the plant will deliver CDR. This will be the first large CDR project being realised in Norway. The cement factory Norcem’s emissions largely stem from the use of fossil fuels, but approximately 10% of the emissions come from biogenic sources.

Civil society response

There are also civil society and industry actors pushing for enhanced CDR policies. In a letter to the climate and environment minister on the 24th of November 2021, right after COP26, the ENGO the Bellona foundation with support from 14 industry actors called on the government to start drawing up the groundwork that is required to scale up CDR, with the following recommendations:

> “1) *Introduce a system with separate targets and accounting for negative emissions, in addition to targets and accounting for emission reductions. 2) Set up a clear definition and criteria for negative emissions. 3) Initiate a public discussion on how negative emissions can best be included in Norwegian climate policy. 4) Cooperate actively with the EU level for a sustainable and effective policy for negative emissions. 5) Enable and facilitate conditions for realising negative emissions*.” (Bellona, 2021).

Update to Klimakur

In late March 2022, the Norwegian Environment Agency published an updated knowledge report complementary to Klimakur due to changes in the international climate regime (Miljødirektoratet, 2022). Among the updated changes was reporting of CDR as explained under section 4.3.5 Accounting: biogenic versus fossil emissions. Consequently, the document suggests employing CCS at three additional facilities (the industry cluster Borg CO_2, Returkraft incineration plant in Kristiansand, and Forus incineration plant in Sandnes) as a policy measure available to the government.

On the three lastest included projects the biogenic emissions exceed the fossil emissions. The new projects were, according to the document, included on the background of three factors. 1) That several industry actors have conducted CCS feasibility studies, and 2) because CCS technology has developed to be able to be delivered faster than suggested in 2020, and 3) that the CO_2 capacity of the Northern Lights project has increased (Miljødirektoratet, 2022). Further, the document emphasises that two industry actors are planning DACCS facilities in Norway, but these are not included because an international framework for accounting is still missing for DACCS (Miljødirektoratet, 2022). Another noteworthy development is that the Norwegian Ministry of Petroleum and Energy announced, in April 2022 that new licences to explore for geological storage in The North Sea and the Barents Sea are awarded to three companies pursuing CO_2-storage services (Olje- og energidepartementet, 2022).

On technological CDR, this analysis has displayed that CCS technology has been a topic in Norwegian policy debate for a long time. It showed that the instruments used to ensure deployment has been the CO_2 tax in 1992, and subsidies to realise CCS at the latest projects. It also showed that the industry and civil society have been engaged in developing CCS, the latest account in Klimakur implies that the industry and civil society are forward-leaning when it comes to CDR.

5.3 History of Norwegian nature-based CDR efforts

Norway has been a strong advocate for climate change and conservation policy in the international policy arena since the 1980s (Hessen & Vandvik, 2022). As early as 1989 Norway was the first country in the world to adopt a national emission stabilisation target (Røttereng, 2017). However, as the national emissions from the oil and gas industry grew, the target became increasingly difficult to maintain and the stabilisation target was later abandoned in 2005 (Tjernshaugen, 2011). During the same period, cost-effective mitigation became the guiding principle through the flexible mechanisms of the Kyoto protocol and created the possibility of meeting national targets through international emission trading (Røttereng, 2017).

Reducing carbon loss in tropical rainforests

Since the mid-2000s Norway’s main nature-based CDR strategy has been to reduce emissions from tropical deforestation through the REDD+ (reduce emissions from deforestation and forest degradation in developing countries) framework. REDD+ is a mechanism where countries in the global north can pay countries with tropical forests to protect them from land-use change to maintain their carbon storage capacities (Røttereng, 2017). The Rainforest Foundation Norway and Friends of the Earth Norway were the policy entrepreneurs who brought funding REDD+ to the political arena in 2007, and Norway's International Climate and Forest initiative were soon after established (Røttereng, 2017, p. 220). Norway has since the program's creation been the single biggest funder with over 40% of the international funding (Angelsen et al., 2017, p. 239). Many have advocated and tried to create a market for REDD+ carbon credits, however, this never materialised. All funding of REDD+ has thus been through governmental aid programs so it has not been possible to count the funding towards national emission accounting (Angelsen et al., 2017).

5.4 Latest development, nature-based CDR in Norway

Norwegian policy directed at the national ecosystems has previously not been focused on carbon sequestration, efforts such as conserving forests have mainly been motivated by increasing productivity that is value-creating, protecting ecosystems and biodiversity, and/or protecting cultural values and human well-being (Hessen & Vandvik, 2022)(Miljødirektoratet et al., 2020, p., 436).

Klimakur

The mitigation strategy document Klimakur 2030, altered the trend by explicitly mentioning nature-based CDR practices as a climate solution (Miljødirektoratet et al., 2020, p., 425). In 2017 the Norwegian forest and land-use sector had a net uptake of 25 Mt CO_2 (Miljødirektoratet et al., 2020, p., 425). A projection of emissions from the land-use and forest sector included in Klimakur shows that without supplementary measures, the emissions from the sector will rise, or in other words, the net uptake will decline to 20,3 Mt CO_2 in 2030. The decline in net uptake is considered due to the ageing properties of the forests (the uptake will decline when the forest reach maturity), increased logging because there will be more available mature forest, and lastly due to decreasing investment in forestry (Miljødirektoratet et al., 2020, p., 421). Logging is the activity that contributes most to these emissions, representing around 2 Mt CO_2 each year. The rise in emissions in the LULUCF-sector is contrary to the EU 'no debit rule', if the emissions from the sector rise according to the projection, Norway will have to report 1,2 Mt CO_2 emissions annually by 2030 (Miljødirektoratet et al., 2020, p., 425).

One of the main tools to reduce emissions described in the Klimakur is directed toward the forestry and land-use sector; increased tree planting, advancing efficient forestry practices, and fertilising the soil to increase the uptake of CO_2 (Hessen & Vandvik, 2022, p., 13). This optimization of the forest productivity will, according to Klimakur, facilitate increased use of wood in long-lived products which have carbon storage capabilities (Miljødirektoratet et al., 2020, p. 443-444).

Civil society response

The World Wildlife Fund (WWF) commissioned a report from the Norwegian Institute on Nature Research on 'Carbon Storage in Norwegian Ecosystems' that was published the same year as Klimakur (Bartlett et al., 2020). The report gives an overview of terrestrial carbon uptake and storage in national ecosystems (Hessen & Vandvik, 2022). Contrary to Klimakur, which gives an overview of the added carbon storage potential achieved by land-use change mainly by tree planting and enhanced forest practices, the WWF report documents existing below- and above ground carbon sinks (Hessen & Vandvik, 2022). The report also comments on the potential consequences on the existing carbon sinks by the measures proposed by Klimakur, the most relevant is summarised:

High-density tree planting as proposed in Klimakur has negative effects on the growth of vegetation underneath the trees (understory vegetation). Understory vegetation is an important carbon sink but is left out of Klimakur's evaluation. In addition, the report highlights that high-density tree planting also can have dramatic effects on ecosystems and biodiversity. Lastly, it is noted that high-density tree planting is vulnerable to effects of climate change such as storms (Bartlett et al., 2020, p. 43). *Forest fertilisation* with nitrogen can potentially have harmful effects by contributing to NOx emissions, a strong GHG. Additionally, fertilisation can have severe negative impacts on local pollution if the nitrogen leaks into important ecosystems, and it can reduce plant and fungal diversity (Bartlett et al., 2020, p. 43). *Afforestation* on new areas that are semi-natural as a measure to increase carbon sequestration, as suggested in Klimakur, is claimed to not have the vast carbon storage potential as proposed and might have negative effects on ecosystems. This is because the vegetation growing in the areas, "grasslands, heathlands and wetlands have a very high potential to store soil carbon, a characteristic that has been largely underestimated, so the plantation of trees in these areas may not render the expected carbon removal levels" (Bartlett et al., 2020, p. 44)

Further, the WWF report advises on how to increase the carbon uptake and reduce emissions from land systems, which enhances co-benefits to ecosystems. Since the data on sources and sinks are scarce and uncertain, and accounting methods have many limitations, it is advised that a precautionary principle should guide decision-makers when considering altering ecosystems (Bartlett et al., 2020). The following measures are proposed:

Instead of afforesting new semi-natural areas, *restoring and maintaining forests and mires* to a more natural state is claimed to have better effects on storing CO2 simultaneously as being beneficial for ecosystems and biodiversity (Bartlett et al., 2020, p.,45). *Longer rotation times* in forestry have been shown to affect the carbon stocks, and thus the carbon content of wood products which in turn enhances the substitution effects (eg. fossil products are substituted with wood products). This measure will also have effects on biodiversity and the growth of understorey vegetation (Bartlett et al., 2020, p.,46). *Continuous-cover forestry,* which is a sustainable forest practice whereby single trees are cut to maintain biodiversity, is suggested as a measure alternatively to clear-cutting. The carbon sequestration capacity is not that different but the effects on ecosystems and biodiversity are considered much better when practising continuous-cover forestry (Bartlett et al., 2020, p.,46). Lastly, *Reduced harvesting* is suggested as a measure to rapidly reduce emissions from the sector. To increase carbon sequestration and protect ecosystems, measures like protecting more forests and restoring formerly managed forests to a more natural state are suggested (Bartlett et al., 2020, p.,46).

New policy instrument - Bionova

The Norwegian government launched in 2021 that they would establish a financial policy instrument named Bionova to realise emission reductions in the agricultural, forestry and aquacultural sectors. The instrument will take the form of subsidies for emission reduction measures, but carbon sequestration measures are also explicitly mentioned. The policy instrument is still under construction and is led by the Ministry of Agriculture and Food in collaboration with the Ministry of Trade and Industry, the Ministry of Climate and Environment, the Ministry of Communal and District Affairs and the Ministry of Finance.

The policy was put on public consultation in March 2022, and it aims to be operative in the second half of this year (Regjeringen, 2022)

6.0 “What are policy instruments used to scale up CDR in other countries and how can changes in regulatory measures incentivise CDR deployment in Norway?”

This chapter will first give an overview of policy instruments that are used or proposed to incentivize CDR in other countries because even though policies are scarce the policy landscape is evolving quickly and more and more countries are developing policies (Lundberg & Fridahl, 2022). Second, it will discuss the possible policy instruments derived from the analysis in addition to some policy instruments proposed in the literature as suitable to incentivise CDR deployment. Lastly, based on the analysis of the different policy instruments, policy recommendations on how Norway could effectively incentivise CDR deployment will be suggested.

6.1 Policies around the world

This section describes policy instruments in other countries and is organised by country (and the EU) where each section starts with a short presentation of the climate targets of each country respectively. The targets are included because they provide context to the policies described.

The EU

The EU has recently updated its 2030 climate target to reduce emissions by 55% compared to 1990 levels. The 2050 target is to reach member-wide net-zero emissions (Schenuit et al., 2021).

The EU - policy instruments

The European Commission considers CDR as a key mechanism to reach net-zero, however, there has been little action to incentivise CDR deployment in the EU so far (Geden et al., 2019). That might change soon as the commission in December 2021 adopted the communication ‘sustainable carbon cycles’(SCS). The SCS is an action plan to increase technological and nature-based CDR in EU countries (European Commission, 2021).

Firstly, the commission has set a removal target for the land sector to remove 310 Mt CO_2 by 2030. ‘Carbon Farming’ is the term used for the practice of incentivizing the agricultural and forestry sectors to deliver removals. The commission plans to deliver the removals by incentivising practices such as afforestation, reforestation, agroforestry, use of catch crops and cover crops, and restoration of wetland and peatlands. It proposes to use established EU programs such as the Common Agricultural Policy, LIFE programme and Regional Development Fund to support the measures. Secondly, ‘Industrial sustainable carbon’ is the term used for technological CDR, and the Commission aims to remove 5Mt of CO2 annually by 2030 with technological solutions. It will use the Innovation Fund and Horizon Europe to financially support implementation (European Commission, 2021).

Most importantly, the commission will by the end of this year (2022) establish a regulatory framework for the certification of carbon removals. The framework will establish monitoring, reporting and verifications standards for removals, which is key to enabling international carbon markets and ensuring harmonised standards and credible CDR (European Commission, 2021).

The United States of America

The official United States of America (US) emission target is to reduce emissions by 50%–52% below 2005 levels by 2030, and the current president, Joe Biden, has stated that the country’s 2050 target is to achieve net-zero (Climate action tracker, 2021).

Nationwide policy instrument (US)

The 45Q tax code is a US nationwide policy instrument intended to incentivize CCS at large point sources that burn fossil fuels to avoid emissions. It leverages tax credits to facilities that apply CCS. While not an explicit CDR policy (Schenuit et al., 2021), a 2019 amendment made DACCS projects that remove more than 100.000 tons of CO_2 per year eligible for a 35 US dollar tax credit for carbon capture and utilisation, and 50 US dollars tax credit per ton captured and geologically stored (Jeffery et al., 2020). Given the current price of DACCS technologies the tax code will not alone fund projects, but together with other funding streams, (such as the Californian LCFS, explained below), it can initiate projects (Naimoli, 2021).

State policy instrument - California (US)

In 2006, California introduced ‘the Low Carbon fuel Standard’ (LCFS) to reduce the emissions from the transportation sector across the state. By setting a declining cap for the carbon intensity (CI) allowed in the life cycle of transportation fuels, the regulation incentivised fuel suppliers to reduce the emissions from the value chain. The mechanism of the policy is marked-based, which opts to be cost-efficient and works like a cap-and-trade system. Suppliers of low-carbon fuels acquire credits and sell them to fuel suppliers that exceed the CI benchmark. In 2019 CDR projects were included in the regulation, projects anywhere in the world capturing CO_2 from the air and permanently storing it can acquire credits and thereafter sell them on California's carbon market (Friedmann, 2019). The amendment is most applicable to DACCS projects. In 2019 the average credit price was just under 200 US dollars. The price of DACCS per ton of CO_2 sequestered is above 200 US dollars so it is still uncertain whether the sector-specific regulation will trigger DACCS deployment (Jeffery et al., 2020).

State policy instrument - New York

In January 2022, a legislative proposal named ‘The Carbon Dioxide Removal Leadership Act’ (CDRLA) was introduced to the New York State Assembly. The proposal aims to help New York reach its 2050 Net-Zero target by using public procurements to finance carbon removals enough to offset the hard-to-abate sectors. The bill proposes to establish a separate target where 15% of the Net-zero target should be fulfilled using CDR - which corresponds to the emissions from the hard-to-abate sectors. That leaves emission reductions to be the foremost priority representing 85% of the emission reduction from the baseline year of 1990 (NY State Senate Bill S8158, 2022). The policy instrument suggested in the legislation is that the state should use yearly reversed auctions from 2025 to attain the emission reduction goal. Reversed auctions are similar to a normal auction, but instead of the buyer bidding on the sales item by offering the highest price, it is the sellers who bid to get the sales offer by offering the lowest price. In this way, the most cost-efficient CDR project who can offer CO_2 removed and securely stored at the cheapest price gets financing from the state. The maximum CDR price is set at 350 US dollars per ton of CO_2 in 2025 and shall increase by at least 5% each year (NY State Senate Bill S8158, 2022).

The policy intends to be technology-neutral; any method that can verify -secure capture and durable storage qualifies for participation, however, it is required that the projects must comply with the concept of additionality which means that the project must be “additional to any prior or otherwise existing or planned CDR”. Here the concept ‘durable’ is important because it opens for storage of CO_2 in a wider array of methods such as in long-lived products like construction materials and plastics. Among the CDR approaches mentioned are DACCS, BECCS, Enhanced Weathering, biochar, marine-based CDRs, and durable storage in products such as mass timber. The bill also specifically points out that other not mentioned CDR approaches are not excluded. Before the bid, the project must get third-party verification to ensure that the project meets the capture and storage with no leakage requirements (NY State Senate Bill S8158, 2022).

When projects are submitted, the department will give each project a score which determines chosen project. The score is based on a set of preferences that - include but are not limited to - price. Other factors valued: scale-potential, the timeframe of delivered CDR, the bidder has tax liabilities within the state, the duration of storage should be at least 100 years, use of resources such as water, energy, and land, gives co-benefits to ecosystems, and does not cause significant harm, CDR-project benefits one or more disadvantaged communities, generates job opportunities within the state, the projects promote equity or environmental justice (NY State Senate Bill S8158, 2022).

Sweden

In the Swedish climate law, there are established separate targets to reach the net-zero goal: the country shall reduce emissions by at least 85% and use ‘additional measures’ for a maximum of 15% of the target by 2045 (Schenuit et al., 2021). Additional measures are identified to be CDR - both technical CDR solutions and actions to increase the CO_2-uptake in the LULUCF-sector - and lastly international offsets (Miljödepartementet, 2020).

Sweden - Policy instrument for Technological CDR

In 2020 the Swedish government launched the governmental inquiry ‘the Pathway to a Climate Positive Future’ (SOU2020:4) which sets out a strategy proposal and action plan to realise the CDR objective set out in the climate law. The strategy is currently in parliamentary consultation and is awaiting implementation (Miljödepartementet, 2020). International offsets are mentioned as an additional measure in the climate law, but due to various reasons, international offsets are given less importance in the 2020 Swedish strategy and will not be discussed in this research (Fuss & Johnsson, 2021).

BECCS is the only technological solution that is included in the inquiry and can be ascribed to three factors. First, BECCS is a quite mature technology, especially the CCS technology part. Second, the CO_2 captured with BECCS is stored in geological storage, which means that the CO_2 storage is seen as permanent. Sweden has not developed national storage sites but Fuss & Johnsson (2021) have made a map of Swedish biogenic emission point sources which shows that many of the facilities eligible for CCS are located along the coastline making it suitable to buy geological storage through the Norwegian Northern Lights project (Fuss & Johnsson, p. 6., 2021). Third, and maybe most important is that Sweden has a large forest industry producing bio-products such as saw timber, pulp, and paper. Additionally, there is an increasing share of the road transport sector (20%) that uses domestically produced biofuels (Fuss & Johnsson, 2021). Consequently, a large share of Swedish emissions come from point sources that release biogenic CO_2, in 2018 Sweden emitted 32.3 Mt CO_2 of biogenic emissions, compared to their total emissions which were 51.8 Mt CO_2 (Fridahl et al., 2020, p.,2). This makes the implementation of CCS on point sources emitting biogenic CO_2 an opportunity to realise CDR through BECCS (Garðarsdóttir et al., 2018). Even though the policy is currently only directed at BECCS, it is noted that more CDR methods will be evaluated for inclusion in later rounds when methods are seen as mature (Miljödepartementet, 2020).

‘The Pathway to a Climate Positive Future’ recommends using the policy instrument reversed auctions to realise BECCS in Sweden. The goal outlined is to remove 1,8 MT of CO_2 each year by 2030 (with an estimated possible increase of 3-10 Mt a year in 2045) (Miljödepartementet, 2020). It sets a maximum annual removal to 2 Mt a year up to 2030 which accounts for financing around 3-4 facilities (Fuss & Johnsson, 2021).

Sweden - Policy instrument for nature-based CDR

Sweden has a lot of natural sinks, mainly in the large forest land which covers just under 70% of the country (Miljödepartementet, 2020, p. 90). In 2018 the net removal in the LULUCF-sector was 42.0 Mt CO_2 (Fridahl et al., 2020, p. 2), LULUCF-sinks are thus not accounted into official climate budgets because that would have enabled the country to become net-zero easily (Fuss & Johnsson, 2021). Only the additional measures to increase the natural sinks that are a direct result of the policy instruments proposed in the inquiry will be accounted into national climate budgets. Counting only the additional uptake is also in compliance with the EU LULUCF regulation the ‘no debit rule’ (Schenuit et al., 2021).

The Swedish forests are well-managed and there is also room to increase the production of sustainable biomass (Fuss & Johnsson, 2021). The strategy emphasises that the underlying conditions for CDR in the LULUCF-sector is that there is an opportunity to increase carbon sinks in the forest land, in addition, to use the bio-resources from the forest to produce renewable raw materials (Miljödepartementet, 2020, p. 90). However, the document highlights the inherent differences in the durability of storage for nature-based measures. Both in comparison to technological solutions that store CO_2 geologically contrary to nature-based where storage durability is more volatile and dependent on human activity. But also, within different nature-based measures. Growing a large boreal tree that stores CO_2 takes up to decades, a planned measure today may have an effect in 2040 while growing cover crops on cultivated land have a more direct impact on the uptake (Miljödepartementet, 2020).

The measures suggested are mainly changes to existing agricultural land (arable and grazing lands). The measures are proposed to be gradually implemented and envisaged to capture the full potential of 1,2 Mt in 2030, except for catch crops that will be fully implemented by 2040. Among the measures followingly, catching crops and rewetting is seen as the most important measures for the CO_2 uptake. 400,000 hectares – of catch crops and cover crops, 50,000 - hectares of agroforestry, 40,000 hectares – of land taken out of production should be used for energy crop cultivation, 100,000 hectares – of afforestation, 50,000 hectares – of land in a later stage of natural overgrowth should be managed to promote growth. There are also proposed policies to gradually rewet previously drained peatland for farming and forestland up to 2040 on 100,000 hectares of forest land and 10,000 hectares of former agricultural (Miljödepartementet, 2020, p. 91-92).

The instruments suggested for increasing carbon sequestration in the LULUCF sector are mainly direct subsidy schemes managed by the Swedish Board of Agriculture. The Swedish Board of Agriculture is given the task of reviewing existing policies that already support some of these measures and designing new ones to realise the above-listed measures. The inquiry advised allocating 10 million SEK to the Swedish Board of Agriculture annually to 2030 for this purpose. It is also advised that the Swedish Board of Agriculture in consultation with the relevant state agencies create criteria for preferred plant species, suitable land for measures, and which areas to prioritise for re-wetting.

The United Kingdom (UK)

The UK legislated in 2019 to reduce emissions to net-zero by 2050 (Lezaun et al., 2021). In national accounting, emissions and removals are weighted equally, and the LULUCF sources and sinks are also included in national inventory reports (Schenuit et al., 2021).

UK - Policy instruments for nature-based CDR

Implemented CDR policies in the UK are mainly directed at the forestry sector (Schenuit et al., 2021). The UK government has an ambition of afforesting 30.000 hectares of land each year by the end of this government period (Lezaun et al., 2021). The UK Forestry Commission established the Woodland Carbon Code in 2011, an incentive scheme to preserve and expand woodland. In 2019 the government established a market to incentivise voluntary actions to increase the uptake of CO_2, named the Woodland Carbon Guarantee. The 50-million-pound scheme is developed so that landowners and individuals can forest land and sell the subsequent carbon removal to the state (Poralla et al., 2021). The Woodland Carbon Code is a framework to monitor, report and verify (MRV) the CO_2-uptake of the proposed projects. The Woodland Carbon Guarantee offers a long term guaranteed price for the CO_2 stored with payment every 5 or 10 years up to the mid-2050 (Poralla et al., 2021).

UK - Policy instruments for Technological CDR

The Royal Society (2018) in an analysis commissioned by the government established that the UK remaining carbon budget after reducing emissions to the greatest degree deemed feasible leaves the UK with a carbon debt that must be offset with CDR. However, “Offsetting these emissions with GGR (CDR) to reach ‘net-zero’ for the UK is possible, but very challenging. It involves deployment of many different GGR methods, and import of biomass” (The Royal Society, 2018, p., 9). Followingly, in December 2020 the UK government announced a CDR innovation program that will identify methods to remove CO_2 and other greenhouse gases on the Mt-scale or greater at a cost under 200 UK pounds or less per ton. The aim is to reduce greenhouse gases to reach UK’s net-zero ambition. The programme aims to be technology-neutral and employs a portfolio approach which means funding different technological solutions. It is highlighted that solutions should be scalable, subsequently DACCS, BECCS and Biochar are the most important technologies. Forestry and land-use change projects, soil carbon sequestration and ocean fertilisation projects are thus not considered. The program will fund five interdisciplinary projects through an application process and a subsequent selection of awarded projects based on a set of criteria (BEIS, 2020). DACCS projects that will be realised through the innovation program are considered to be ready to be deployed and remove CO_2 in the early 2030s. (BEIS, 2021, p., 189)

In October 2021 the UK government launched its “Net Zero Strategy: Build Back Greener” which sets out an ambition to remove at least 5 Mt CO_2 per year by 2030, and around 23 Mt by 2035 (BEIS, 2021). The strategy considers both nature-based and technological solutions as necessary contributors to the target. The UK has its own Emission Trading Scheme (ETS) where emission allowances are traded among emitters. The government proposes to include CDRs in the UK ETS to make a marketplace for CDR. This would allow emitters to compensate for their emission by buying CDR credits. However, due to the large investment costs of the relevant CDRs, it is also noted that there might be a need for initial government investment for developers. While there are no policy incentives for technological CDR today, the government will consult on the instruments to incentivise technical CDR in the spring of 2022 to decide on the preferred mechanisms. A policy directive is expected to be in place by the end of 2022 (BEIS, 2021, p., 194).

Australia

Australia has pledged to reduce emissions by 26-28% by 2030 from the base year 2005, some states have committed to net-zero by 2050 but there is no national net-zero target. LULUCF sources and sinks are included in national inventory reports (den Elzen et al., 2019).

Australia - Policy instrument for nature-based CDR

In Australia, the Direct Action Plan, implemented in 2014 is the country’s main strategy to reduce emissions. The government holds reversed auctions to buy voluntary nature-based CDR at the lowest cost across all sectors with funding from the Emission Reduction Fund (Nong & Siriwardana, 2017). The nature-based CDR projects that are being realised through the plan are called vegetation methods and include natural regeneration, avoided deforestation, afforestation, and improved grazing practices (Evans, 2018). Initially, there was a 100-year permanence requirement for the vegetation methods, however, the durability requirement was seen as a barrier for some projects. Thus, an option for projects with 25 years of durability of sequestration was implemented with a 25% penalty on awarded credits (Evans, 2018). In the bidding rounds, the price on the project bids is sealed so it’s not possible to generate an average cost estimate on bids, but the principle is that the lowest bids per ton of CO_2 avoided or removed are selected by the Clean Energy Regulator, who also regulates monitoring, reporting and verification (Nong & Siriwardana, 2017).

New Zealand

New Zealand’s emission reduction target is to reduce emissions by 30% by 2030 compared to 2005 (Leining et al., 2020), and in 2019 it was set into law that the country shall reduce emissions to net zero in 2050 (New Zealand Ministry for the Environment, 2022). Abatement and CO_2-removals are treated equal and included in national emission accounting (Schenuit et al., 2021).

New Zealand - Policy instruments for nature-based CDR

In 2009, New Zealand introduced its national emission trading scheme (ETS) that covers most of its economic sectors by applying sector-specific obligations to 52% of New Zealand’s emissions (Leining et al., 2020). The forestry sector is covered with obligations for deforestation and credits for afforestation. Forests that have been in place before 1990 have deforestation obligations and forests established after 1989 are eligible for credits with a clause of punishment if reversed. In 2019 the government announced the inclusion of emissions from the agricultural sector in the ETS, which can incentivise CDR in the sector (Leining et al., 2020).

In New Zealand’s ETS, emissions and removals from nature-based CDR (mainly forestry) are treated equally to emissions or avoided emissions, meaning that credits obtained from CO_2-sequestration can be traded to emitters to offset their emissions. Counting removals for nature-based approaches is an anomaly; other ETS’ exclude the LULUCF-sector such as the EU ETS and the Californian ETS (Schenuit et al., 2021). The net offsetting by the forestry sector accounted for 30% of the total emissions in 2017 (Leining et al., 2020).

6.2 Discussion of policy instruments

To address the question of what regulatory changes can be made to incentivise CDR in Norway, some key traits displayed in the analysis of the CDR regime in Norway must be considered when designing new policy instruments to incentivize CDR. First, the analysis of barriers and opportunities showed that the main barrier to implementing technological CDR are a high investment and operational costs, which means that the realisation of BECCS and DACCS hinges on governmental policy interventions that facilitate long-term financial support. Further, nature-based solutions are inherently heterogeneous and require differentiated support based on their characteristics.

By giving an overview of existing and in-the-making policies, a multiplicity of different policy options was presented as possible pathways to incentivize CDR deployment. This section will discuss the suitability of the policies derived from the analysis above as well as policy instruments proposed in the literature to incentivise CDR in Norway. It should be noted that there are advantages and disadvantages of any given policy instrument (IPCC, 2007).

The first step in creating a new policy design is creating policy goals and objectives (Vonhedemann et al., 2020). The respective objective here is to ensure the deployment of CDR solutions. And as discovered in social and political barriers and opportunities, a specific national target for CO_2 removal should be implemented to ensure the additionality of using CDR. Moreover, setting a target for CDR can contribute to setting a specific goal for the volume of removals it necessitates, which thus can guide the use of a policy instrument and enable long-term planning. The second step in a policy design is choosing the suitable policy instrument to attain the goal (Vonhedemann et al., 2020), to do so the criteria for evaluating the policy instruments must be established. The following four criteria will be used in the assessment of policy instruments suitable to scale up CDR in Norway.

Administrative feasibility refers to the ability of the bureaucracy to implement and administer a policy instrument effectively.

Political feasibility refers to whether the policy is likely to be accepted by politicians, industry, and the public.

Cost-effectiveness refers to whether the policy can achieve the goal at costs-optimally.

Environmental effectiveness refers to whether the policy is likely to assure the removal of CO_2 and prevent environmental degradation.

These four criteria will guide the following discussion of different policy instruments (IPCC, 2007).

6.2.1 Business as usual pathway

The concept of carrot or stick refers to what type of policy instruments are being implemented to create a preferred outcome; they can be based on soft (e.g., subsidies) or hard (taxes or regulations) power. Illustrative examples are the CO_2 tax directed at the oil and gas industry in 1992 that triggered the deployment of CCS to avoid fossil emissions from the oil and gas industry at Sleipner and Snøhvit displayed in sub-RQ2. However, since biogenic emissions are not covered by a tax, and removing CO_2 mainly is a public good, increasing existent CO2 taxes will not lead to the deployment of technological CDR, unless they are made explicitly eligible under such a system (Poralla et al., 2021).

Additionally, sub-RQ2 showed that the realisation of CCS on Norcem is a direct effect of government subsidies guaranteed for 10 years, and The City of Oslo facilitated private financing to deploy CCS at Oslo Fortum Varme. Likewise, the past efforts to reduce deforestation and subsequent carbon loss in the tropical forest through the REDD+ program has come from subsidies over the national budget. The advantage of using subsidies is that it is usually a popular measure among the targeted industry, the downside is that if not sourced from a special tax, the financial burden incurred by the government is considerably higher than for other types of instruments. High government spending on a selected group of actors can also create resistance among other societal groups.

The trajectory of establishing two new industrial CCS plants indicates that technological CDR deployment could occur incrementally under the current policy framework. However, these efforts have taken decades to establish, and demand a substantial amount of administrative resources because the government is involved in the process from selecting projects to fund to evaluating the involved costs. If Norway wants to move beyond incremental change to a significant scale of removals, further policy interventions are imperative. There are various ways in which regulatory measures could be used to finance or force the deployment of CDR, the following sections will discuss relevant existing schemes.

6.2.2 Carbon takeback obligation

A design proposed in the literature to scale up CDR is to impose a supply-side “Carbon Take-Back Obligation” (CTBO) on fossil fuel extractors and importers (Jenkins et al., 2021). The obligation mandates the applicable parties to remove and geologically store a progressively increasing amount of CO_2, eventually reaching an equal amount of CO_2 to what is generated from their activities and products. The obligation is mainly aimed to enable a scale-up of DACCS, which means that the price of DACCS would direct the price of the obligation. Initially, the obligation percentage would be small while the cost of DACCS is high, but as prices decline the obligation is designed to be increased. The advantages of the CTBO are that it offers simple and cheap bureaucratic governance; it is easily controlled since the price of DACCS determines the price of the obligation. Ultimately, it is a stick measure that would force a rapid scale-up in pace with the continued use of fossil fuels (Jenkins et al., 2021). The CTBO is the counterpart to the traditional demand-side CO_2 price. The downside of such an obligation is that the industry would most likely defy the scheme.

6.2.3 Reversed auctions

Reversed auctions are a subsidy mechanism for the state to cost-efficiently buy removals from companies that can deliver CDR. The price is set by the buyer and the time horizon is set by the state. As mentioned above, with reversed auctions it is the buyer who requests sellers to place bids and the principle is that it is the one who can offer the service to the lowest price who wins the bid. The policy instrument can both be used for nature-based solutions such as in Australia, for both categories being technology-neutral as proposed in New York or solely for one technology as proposed in Sweden. The mechanism is suitable for CDR because it lets the government either govern by a proposed volume of removals or by a restricted budget (Lundberg & Fridahl, 2022). For example, Sweden where they govern by a yearly given removal target. Since the cost of technological CDR is still uncertain and fluctuating across projects, an auction eases the process by letting the sellers propose the price. The budget or volume can be adjusted accordingly. However, if reversed actions are held technology-neutral, meaning that all durable methods to remove carbon can compete, the selection process where methods are valued against each become difficult because the CDR methods have vastly different characteristics (Lundberg & Fridahl, 2022). As mentioned above, the New York proposal has defined a set of criteria that bids get a score based on to select the preferred projects. There have been raised criticisms over Australia’s reversed auction system for nature-based methods not being additional. The reasoning is that the ‘abatement at lowest cost’ mechanism produces an incentive to choose projects that would have occurred without the mechanism, causing adverse selection. (Burke, 2016) (Blakers & Considine, 2016)(England, 2016). This is less likely for BECCS or DACCS since the investment and operational costs are considerably higher. A homogenous group of bidders are more comparable; hence the selection process is easier. However, it excludes possibly promising solutions. In Sweden, since the wood processing industry is large there is a potential for many bidders to be part of the process. However, in other countries where the potential for BECCS as an existing industry is smaller, only including BECCS might lead to few bidders because it is otherwise an immature technology on its own. Additionally, many facilities eligible for CCS have both biogenic and fossil emissions, if the support only covers the biogenic emissions some suitable actors might not be able to compete because covering the costs for the fossil emissions is too high.

6.2.4 Contracts for Difference

Contracts for difference (CFD) is a subsidy delivered through a financial contract, CFDs has primarily been used as a mechanism to make renewable energy technology competitive in the energy market. Since renewable energy historically has been less competitive than fossil fuels, governments have used CFDs to cover operating costs that are above the market price (Welisch & Poudineh, 2020). The financing instrument is also newly introduced to support CCS on fossil emission point sources in the Netherlands through the SDE++ program. The government provides financial support to the operators by covering the price above the EU ETS price. Because these facilities are covered by the EU ETS, establishing CCS eliminates the costs of the removed emissions, so the corresponding price is taken by the operators (Andreas, 2021). The CFD subsidy in SDE++ is awarded through holding reversed auctions where projects are bids to offer, respectively the program is guided by a lowest-cost approach. Even though the CFDs are proposed as a possible financing mechanism in literature (Poralla et al., 2021, p., 24), a blueprint for how the instrument would work on CDR is absent. In general, for Cfd to work on CDR a comparable baseline to the EU ETS price or energy price would have to be established by the government, to differentiate the reasonable cost taken by the operator and the government.

6.2.5 Emission trading system

One option to incentivise the deployment of both nature-based and technological CDR is to integrate it into a cap-and-trade system. National carbon offsetting schemes like the Californian LFCS system and the New Zealand ETS allows companies to offset their emissions through buying CDR credits. The UK is also considering the inclusion of CDR in its national ETS to incentivize deployment. Using market-based systems allows for cost-optimal emission reductions. However, a problem with allowing CDR to enter such emission trading systems is that it allows participants to buy credits and thereby continue emitting. Using CDR to offset occurring emissions does not incentivize emissions reductions and can create socio-technical lock-in mechanisms that sustain the use of carbon-intensive fuels (Jeffery et al., 2020)(McLaren et al., 2019). As established in sub-RQ1, emissions reductions and CDR must occur dually, consequently, a cap-and-trade system could create a perverse incentive for companies to remove CO_2 instead of abating it. Additionally, allowing occurring fossil emissions to be offset by nature-based methods with risks of reversal and uncertain storage durability may create adverse climate impacts. As Jefferey et al. (2020, p., 20) put it “Financial support should positively reinforce ambition raising while offsetting activities have the potential to present perverse incentives that undermine this”. On the other hand, introducing technological solutions at current prices creates the low risk of creating perverse incentives. However, the policy instrument does not guarantee deployment, because it is not certain that the system will provide enough financial support to cover investment and operational costs. On a regional level, there are discussions of introducing BECCS and DACCS to the EU ETS (Rickels et al., 2021), which would apply to the Norwegian industry. However, Norway does not have a national ETS, so creating one just for the sake of incentivising CDR is unrealistic considering the administrative processes, the political efforts and the cost involved.

6.3 Policy recommendations

This section will - based on the analysis of barriers and opportunities to implementation, the Norwegian context, and discussion of policy instruments - suggest appropriate policy instruments that could scale up CDR in Norway.

6.3.1 Policy recommendation: technological approaches

The analysis of the Norwegian CDR regime shows that the industry in Norway, with support from the government, is engaged in establishing CCS plants and infrastructure which is relevant and supportive of further technological CDR initiatives (Schenuit et al., 2021, p.14). Additionally, there has generally been high public acceptance for CCS deployment, which implies that there are reasons to believe that CDR approaches also can be welcomed by civil society and the public.

Due to access to renewable energy, freshwater supply and carbon transportation and storage infrastructure, Norway holds favourable conditions for deploying DACCS as these are the main near-term barriers to deployment. Concerning BECCS, Norway has several industry point sources that could apply CCS to create CDR, such as cement and metallurgical industries, waste management and some biomass-based industries (wood processing, biofuel and biogas production).

Judging from the analysis of possible policy instruments, Reversed auctions stand out as an appropriate measure to scale up technological CDR in Norway. Holding reversed actions would be administratively feasible, it requires the state to set up the auctions and surrounding framework. It is easily governed because it allows industry actors to carry out the technical feasibility studies and settle the price. Additionally, the policy instrument is suitable because it can be steered by the CDR target and assure that the policy goal is achieved, securing effective removal of CO2. Some guidelines and criteria could be established in the reversed auction framework that prevents environmental degradation. The auctions could be open for both DACCS and BECCS which would stimulate technological development, but also assure that the most cost-efficient projects are chosen. The instrument dictates that it is the state who buys the removals from the industry actors, implying that it would be politically feasible at least for the industry actors. However, it is a subsidy, meaning that it would involve costs taken by the authorities, so implementation is dependent on political will and prioritization.

6.3.2 Policy recommendations: nature-based approaches

Throughout the analysis, there have been identified several barriers and opportunities to nature-based CDR approaches. The analysis of nature-based CDR developments in Norway showed that there are various opinions about which measures are the most climate-effective and environmentally sound measures to implement. This indicates that there still exists large uncertainty about the complex features in the climate system and nature's response to different interventions. As such, it is necessary to fund research that aims to develop a deeper understanding of the Norwegian terrestrial and aquatic ecosystems, and subsequent suitable measures to preserve and enhance carbon sequestration and its respective effects of these. The large uncertainties, but growing knowledge about the inherent functions of ecosystems demand an iterative policy process where new measures are revised when new knowledge is gained.

It became clear in the analysis of nature-based CDR policy in Norway that there has not been significant deployment of measures that are strictly introduced to secure or enhance carbon storage in ecosystems domestically. However, previous REDD+ efforts show that Norwegian policymakers are engaged and willing to pay to protect natural carbon sinks.

Based on the analysis of policy instruments, several concerns limit the range of suitable policy instruments for nature-based approaches. The risk of reversal and durability of storage makes measures preferring lowest-cost approaches less attractive, because the cheapest options might not be the most environmentally and socially sound measures. If reversed auctions were to be held for nature-based approaches, it would require administrative resources to set stringent criteria for environmental co-effects and selection of projects. Since nature-based approaches require differentiated support based on their characteristics, a subsidy-based policy without a competition aspect would be effective to grant funding to projects on a case-to-case basis. Since the government is already in the process of establishing Bionova, which aims to increase nature-based CDR and is governed by competent authorities, it presents itself as a suitable instrument to fund projects that aim to secure and enhance carbon storage in Norway. Since this thesis proposes to establish a separate target for CDR, Bionova and the necessary funding of it should be guided by such a target to ensure that the policy goals are achieved.

7.0 Conclusions

Due to the respective limitations to all CDR approaches discovered in the analysis of practical barriers and opportunities, governments should adopt a portfolio approach where multiple CDR solutions are evaluated and implemented on a modest basis. However, many of the barriers described occur when CDR is applied on a large-scale globally. National CDR efforts must therefore be developed according to national bio-physical, social, political, technical, and economic features. As seen in the analysis of policy instruments in other countries, the Swedish proposal only suggests implementing BECCS due to their large proportion of bio-industries. CDR will not be perfectly developed equally across the globe, so taking advantage of national CDR opportunities would enable the most optimal CDR deployment globally. Moreover, to ensure CDR does not deter emission reduction, Norway could separate targets as described in political and social barriers and opportunities. A separation could assure that policymakers treat CDR as an additional measure to traditional mitigation enabling both robust decarbonisation and CDR scale up (McLaren et al., 2019). In Sweden the 15% additional measure target is based on removal potential, in the New York proposal, it is based on the size of the ‘hard-to-abate’ sector. Possible justifications for such a Norwegian target could be the ‘hard-to-abate’ sector, scope 3 emissions from the oil and gas industry (though probably less politically feasible) or analysing the CDR potential in Norway.

The analysis of practical barriers and opportunities showed that the main near-term challenges for BECCS and DACCS are financial incentives to cover the high costs and access to transportation and storage infrastructure. Moreover, it showed many of the same traits for nature-based approaches, namely that many barriers identified appear in the long term on a global scale. On Nature-based approaches the uncertainty about the durability of storage must be considered when designing policy, long-term management practices can assure increased credibility of using such approaches.

Assessing political and social barriers and opportunities perpetuated that some inherent traits of CDR must be taken into consideration upon implementation. Most noteworthy for policymaking is how communication affects public perception which can be decisive for the viability of CDR efforts. The latter relates to mitigation deterrence where separating targets for emission reductions and removals can contribute to clarity around CDR's role as a climate solution.

Looking into the history of technological CDR in the Norwegian policy regime showed that Norway has been a pioneer in developing CCS technology. It also indicated that industry and civil society actors have been engaged in the development. The latest developments on CDR in Norway showed a new spike in political will to ensure both CO2 capture at point sources and the establishment of CO2 storage infrastructure. The addition to Klimakur which was published in 2022 revealed that industry actors are independently executing feasibility studies to deploy CCS and that there are DACCS operators keen on establishing in Norway. This in turn implies that a possible policy instrument to effectively incentivise deployment would be timely.

Giving an overview of existing policies in a handful of other countries showed various ways how policy instruments can be designed. Further, it showed that the instrument chosen is related to national contexts and integration with other policy instruments. Based on the discussion of instruments, reversed auctions seemed like an appropriate instrument to incentivise technological CDR in Norway. Additionally, using the already established Bionova seems like an applicable instrument to incentivise nature-based solutions.

There are still many uncertainties about the CDR's roles in reaching the international climate targets, so further research on all aspects of CDR is necessary. With regards to the specific topic in question, the implementation of CDR in Norway, this thesis has only completed a preliminary and exploratory policy analysis. Thus, conducting a full policy analysis to thoroughly evaluate the effects and suitability of different measures is advised.

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