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Carbon Capture and Storage in a Climate Policy Perspective: The Case of Norway

Trondheim, June 2011

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Acknowledgements

I wish to extend thanks to my academic supervisor, Gunnar Fermann, for valuable guidance and support throughout the process leading up to this text. I truly appreciate your confidence in this project and me. I also send great thanks to my interviewees, Inger Østensen, Øyvind Christophersen, Aage Stangeland and Eirik Frøhaug Swensen, who generously found time to share their knowledge and insights. I thereafter wish to thank the Programme for Industrial Ecology at NTNU for sponsoring travel expenses related to these interviews. I am also grateful for editorial help given by Anna Theodora Barnwell, Inger Johanne Sodeland and Eivind Hageberg. Thank you for contributing vital input. However, any shortcomings in the thesis – factual or interpretive - are my sole responsibility.

I further send greetings to my dear friends and peers at the Industrial Ecology Programme for making this two eventful years of master studies in Trondheim. The same goes to my other friends and fellow students. Having had the opportunities to attend the IEA Interdisciplinary Carbon Capture and Storage Summer School in Longyearbyen followed by exchange studies in California, were experiences that gave inspiration and momentum to write this thesis. A big thanks goes to those who made that possible. Finally, I wish to thank my ever-supportive family. You are the best.

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Trondheim,
June 2011

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

BAU – Business As Usual

CC – Climate Change

CCS – Carbon Capture and Storage

CCU – Carbon Capture and Utilization

CDM – Clean Development Mechanism

CHP – Combined Heat and power Plant

CO_2-eq – CO_2 equivalent

COP - Conference of the Parties

CP – Climate Policy

CSLF – Carbon Sequestration Leadership Forum

EEA – European Economic Agreement

EU ETS – European Union Emissions Trading Scheme

EUR – Euro (€)

GHG – Greenhouse Gas

GWP – Global Warming Potential

IEA – International Energy Agency

IPCC – Intergovernmental Panel on Climate Change

LCA – Life Cycle Assessment

NCS – Norwegian Continental Shelf

NOK – Norwegian Krone (Kr)

NPD – Norwegian Petroleum Directorate

OED – Norwegian Ministry of Petroleum and Energy (Olje- og Energidepartementet)

TCM – Technology Centre Mongstad

UNFCCC – United Nations Framework Convention on Climate Change

USD – United States Dollar ($)

1. Introduction

Fossil fuels will remain the backbone of human energy systems over the coming decades, the International Energy Agency (IEA) estimates. Indeed it is projected that absolute consumption of coal, oil and natural gas is estimated to significantly increase as the world's demand for energy grows by 35% over the next three decades (IEA 2010c). In a climate change mitigation context this is bad news. The question arises as to what can be done to avoid increased carbon dioxide (CO_2) emissions resulting from increased consumption of fossil fuels?

Carbon Capture and Storage (CCS) offers the possibility of limiting CO_2 emissions to the atmosphere from fossil fuel combustion. By capturing CO_2 and storing it away from the carbon cycle, CCS may contribute to limiting greenhouse gas (GHG) emissions from fossil energy consumption causing human-induced climate change (Metz, Davidson et al. 2005). Widespread CCS deployment has been forcefully argued as a key contribution allowing for global GHG emissions to peak by 2020 and be reduced by 25% by 2050. Such emission cuts are required in order to limit global average temperature increases to 2°C rise within this century, according to the Intergovernmental Panel on Climate Change (IPCC) (Metz, Davidson et al. 2007).

More specifically, IEA argues that CCS has the potential to account for 10Gt avoided CO_2 released to the atmosphere by 2050 (IEA 2008). In this way CCS is assumed to account for up to 19% of the global emissions cuts needed to prevent "dangerous climate change," making the concept a potentially significant GHG abatement strategy. In order for CCS to function as a climate policy instrument, policy makers must fulfill two conditions: (a) continued interest in widespread fossil fuel consumption under (b) a regime where GHG emissions are constrained (Meadowcroft and Langhelle 2009a: 268).

CCS requires, as the label indicates, advanced integration of diverse technologies throughout the system. Main processes include capture of CO_2, transportation, injection, storage and monitoring of storage sites.

On an industrial scale, this has barely been done before. Deciding to engage in CCS as a climate policy strategy will therefore require a holistic approach from a host of relevant decision makers at different levels in various corners of the world. Studies done on the prospects of commercial CCS implementation have found that cross-border CO_2 transportation and storage might be beneficial from an economics of scale point of view – the more emission sources linked to the system, the lower infrastructure costs (ElementEnergy 2010). CCS activities of such scale would require close international cooperation not only to settle regulatory issues, but also to coordinate incentive mechanisms and developing this new technology under overlapping international, regional and national realms of energy, innovation and climate policy.

This indicates that the challenges of political and economic engineering are as great as the challenges of technological engineering. It is therefore safe to say that partly divergent logics of political feasibility, economic cost-effectiveness, and technological efficiency need to be harmonized in order to materialize the promise of CCS as a CO_2 mitigating policy instrument.

Norway is a country where CCS has gained a remarkably strong foothold. In the Norwegian approach to reducing GHG emissions, CCS is second only to the strategy of establishing transnational emission quota markets (Fermann 2009). The two strategies are, of course, not mutually exclusive. While markets for emission permits are favored by the Norwegian government for its perceived cost-efficiency in achieving GHG reductions, the CCS track is described as the glue merging national interests in continued oil and gas exports with the country's self-image as environmentally progressive (Tjernshaugen and Langhelle 2009). Expressed as concern over climate change, the government points to the IEA energy projections presented above to underline the importance of CCS as a GHG reducing measure also in a global setting (St. Meld 8 2008-2009). On the domestic arena, building gas power plants with CCS has been framed as the solution to the polarized "gas power debate", which I will come back to later in this text (Tjernshaugen and Langhelle 2009).

Presented as a key instrument in the government toolbox, CCS plays a major role in Norwegian climate policy. The impression made is that CCS may prove fundamental in solving what is increasingly seen as a particular Norwegian Gordian knot: Namely, the difficulty of harmonizing Norway's fossil fuel dominated exports economy with Norway's GHG reduction commitments. The Norwegian CCS involvement has been described as world leading – both in terms of public support, industrial know-how and early implementation (Fermann 2009: 16-17). Symptomatically, two of the world's five existing commercial CO_2 storage projects are found in offshore Norway (Ministry of Petroleum and Energy 2010b).[1]

Norway is committed under the Kyoto Protocol to the UNFCCC to lower its GHG emissions to 101% of the 1990-baseline by 2012 (UNFCCC 1998). Domestically, the so-called "climate compromise" commits Norway to reducing its GHG emissions by 30% against the 1990-baseline in 2020 and by 2030 be "carbon neutral" using tradable permits to compensate the remaining emissions in Norway (Ministry of the Environment 2008).[2] Norwegian climate change mitigation policy also serves to fulfill the national sustainable development strategy, as one out of seven highlighted policy fields. Here, progress on sustainable development in the climate policy area is measured as *GHG emissions related to the national Kyoto obligation* (Ministry of Finance 2009b). Sustainable development and climate change policies are understood as complementary aspects of the same ambition.

[1] The other three are found in Algeria, Canada and the United States (Ministry of Petroleum and Energy 2010b)

[2] Recently, concern about the government's commitment towards the set targets and timetables has grown following the prime minister's failure to answer questions on the release of a delayed climate policy white paper in 2011.

1.1 The Research Question

Against this backdrop, the present study investigates conditions for CCS becoming an effective GHG mitigation measure in Norway and thus making a substantial contribution to harmonize economic and environmental interests at the national and international levels. I assume an institutional approach to political economy where political priorities, expressed as institutionalized framework conditions in a market economy, shape conditions for economic activities (Stilwell 2006). What is “cost effective” is therefore not an absolute term in many cases. This foundation, linked with the understanding of CCS deployment as a phasing-in of new technology, point at political, economic and technological aspects as relevant elements of study to explore the Norwegian CCS effort in a climate policy perspective. The research question reads as follows:

> *Under what framework conditions – political, economic, and technical – may CCS function as a climate policy instrument in a Norwegian context?*

I pursue three objectives when addressing the research question. First, I seek to give the term ”climate policy instrument” an operational definition. [3] In order to account for qualitative differences in performance, I wish to classify types of climate policy instruments in a typology. Second, I seek to identify the relevant framework conditions that affect the fulfillment of CCS as a climate policy instrument in a Norwegian context. This allows assessing how easily the Norwegian CCS strategy can be deployed on the ground and what challenges need to be overcome for it to materialize. Third, having that model in place, I wish to evaluate to what extent the Norwegian CCS commitment may function as a climate policy instrument using the developed typology.

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[3] ”Climate policy action”, ”GHG abatement option”, ”climate action”, ”climate change policy”, ”mitigation efforts”, ”climate policy tools”
often refer to similar policies and actions which are imprecisely labeled ”klimatiltak” and “klimapolitikk” in Norwegian. These terms will be discussed and focused appropriately in chapter 2.

The present study may contribute to the wider discussion on how to innovate "smart" policy instruments capable of serving seemingly conflicting policy goals. This might contribute to increased means-goals efficiency in (climate) policy development and also improve the chances of building winning political coalitions on what policy measures to apply. In that sense, the text aims at addressing the effectiveness of CCS as a climate policy instrument in Norway.

While the research question points in direction of a country-specific study, the development of criteria for climate policy instruments and framework conditions for CCS application may be of value as an analytical approach for other country-specific studies as well. As a study on conditions for CCS as a climate policy instrument in Norway, it could hopefully produce results of relevance in other empirical contexts. This thesis can therefore also be read as a conceptually exploratory, where the Norwegian CCS case serves illustrative purposes.

That being said, this text is best understood as a case based analytical narrative, rather than a strict variable analysis or a conceptually explorative study (Hancké 2009). Running the risk of stating the obvious, I emphasis presenting a logical argument where conclusions follow from the premises. The argument should be based on a model that fit the data and the theoretical starting point, despite the fact that the research design borrows from different stylized research approaches.

This may sound like an ambitious study at best, including normative, explorative and explanatory elements. In order to maintain analytical value, certain scope limitations and specifications are required: Why is Norway as the chosen empirical case? What are the political, economic and technological framework conditions under scrutiny and how is this choice of variables justified? What system perceptions, political, technical and economic, come to play when studying a "Norwegian context"? What other methodological choices contribute to shed most light on the research question? These questions are discussed in the remainder of this chapter.

1.2 Why Norway?

Both potentially comparable and unique characteristics of the Norwegian CCS effort add up to an interesting case for study. The country has operative experience with CCS from its offshore CO_2 separation and storage projects. Norway has for years supported CCS in international climate policy forums. By 2012, Technology Center Mongstad (TCM) will be operational as a pioneer test center for CO_2-capture technologies. In 2016 Norway will decide whether to build a first-of-its-kind full-scale CCS system for gas power plant and refinery Mongstad (Ministry of Petroleum and Energy 2010b). The investment decision for the Mongstad full-scale project has been delayed several times leading up to the current "2016 timetable". This has caused uncertainty about the political commitment towards the project in particular and the CCS concept in general (Brekke and Rønneberg 2011). Still, CCS holds a peculiar standing as a strategic policy track in Norway. What may be said, however, is that rhetoric in the national CCS discourse has shifted from CCS only being framed as the compromise in the national gas power debate and towards a wider CCS technology development track rationalized by prospects of global application. I will come back to this in chapter 4.

Norway differs from most CCS engaged countries in three aspects. First, CO_2 storage in Norway can be done offshore and therefore away from widespread popular concern. The perceived risk of leakages from CO_2 deposits is limited. As opposed to countries like Germany, public acceptance is not a contested issue in the Norwegian CCS context (Ashworth, Boughen et al. 2009, Fischedick, Pietzner et al. 2009). Secondly, Norway is one of out few countries prioritizing CCS from natural gas combustion.[4] Other CCS involved countries focus on coal as energy input. Third, hardly any other countries' governments actively build, operate and own CCS plants. The Norwegian government's Gassnova enterprise takes on these three roles (Gassnova 2011).

[4] Also the Netherlands look at CCS from natural gas combustion (Vergragt 2009).

Although the analytical unit refers to Norway as a country in particular, one should note how different system perspectives prescribe different boundaries in terms of energy flows and "entities of climate action" to name a few. Recognizing existing and future cross-border infrastructure for energy and CO_2 transportation, global consequences of CCS technology development and wider political units for climate action and accounting, I also address the implications of such system perspectives. These considerations put the Norwegian CCS commitment in an international context that may widen the relevancy of the findings at hand.

The combination of factors above makes Norway an interesting testing ground for approaching this research topic. The next section presents some further clarifications on methodological choices and the division of labor between chapters.

1.3 Layout and Division of Labor between Chapters

This section accounts for further methodological specification, as well as for the structure of the study in terms of division of labor between chapters. The primary source of data collection used is document review. Empirical literature used can be split into four categories: (i) Academic contributions in journals and books. This literature can in turn be divided into different branches spanning from general capture technologies to context specific regulatory issues and Norwegian political circumstances. (ii) Publications from applied research on CCS ambitions and energy projections, which usually are written by actors with a CCS promoting agenda, like the IEA. (iii) Policy documents from governments, debates in parliament and private stakeholders, ranging from international organizations to industry. [5] (iv) Popular media and niche publications, like *Teknisk Ukeblad* and the *Carbon Capture Journal*.

[5] "Stakeholders" include but are not limited to:
- International and intergovernmental organizations (e.g.: IEA, UN, EU, IPCC),
- National governments (e.g.: Norwegian Ministry of Petroleum and Energy),
- Industry (e.g.: Statoil, Aker Clean Carbon),

As a secondary source of data, I have conducted four semi-structured interviews with resource personnel on the Norwegian CCS context. Information obtained from the interviews has been used to establish an informal overview of the Norwegian CCS and gas power contexts and fill remaining information gaps.[6] The selection of informants is not based on a wish to confer with stakeholders 360 degrees, but rather to learn from a few, key experts in the field.[7] Considering that existing literature on CCS in a climate policy perspective is limited (with a few noteworthy exceptions like Meadowcroft and Langhelle (2009a) and Tjernshaugen (2010)), I position this study among the existing contributions as the relevant issues are presented throughout the text.

Following this introduction, chapter 2 elaborates on the question: what is a “climate policy instrument”? The chapter starts off by defining what “mitigating climate change” means and the introduction of the global warming potential (GWP) indicator. I thereafter propose a definition of “climate policy instrument” and suggest a typology in order to classify different kinds of policy actions that contribute to GHG abatement, spanning from *end of pipe solutions* to *transitional measures* and *sustainable development*. When pointing at the function, effectiveness or performance of CCS as climate policy instrument in this text, I refer to the concept’s attributes as such as the term is operationalized in this chapter. Particular attention is given to the role of technological innovations as solutions to climate change mitigation. This conceptual and operational clarification of the dependent variable is a necessary preamble to the subsequent evaluation of Norwegian CCS policies, which takes place in chapters 4 and 5.

- Environmental Non-Governmental Organizations (ENGOs) (e.g.: Bellona, Zero).

[6] Interviewees include the following informants:

- Deputy director Inger Østensen, Norwegian Ministry of Petroleum and Energy
- Senior advisor Øyvind Christophersen, Norwegian Climate and Pollution Agency
- Special advisor dr. Aage Stangeland, CLIMIT, Norwegian Research Council
- PhD student Eirik Frøhaug Swensen, Center for Sustainable Energy Studies, Norwegian University of Science and Technology (NTNU)

The respective interview guides are presented in Annex I

[7] As part of the conditions for the interviews, the informants have given their permission for the occasions where they are referred to in the text. However unfortunate, I have not been able to retrieve such permissions from all informants by the time this thesis was printed. I use anonymous footnoting in the instances where interviewees should be referred to, but where permissions are not yet given.

Having established what are “climate policy instruments”, chapter 3 presents the political, economic and technological framework conditions likely to influence the extent to which CCS can be considered as such and be materialized in a Norwegian setting. I focus on understanding how CCS can perform as a climate policy instrument given that the concept delivers as promised. Assessments of technical framework conditions take a simplified, yet necessary, look into the technical feasibility to deliver at acceptable performance and cost. In this chapter are the technical stages of an integrated CCS project and main barriers for its further implementation presented as well. Economic framework conditions relate to factors making CCS more or less cost-efficient compared to other GHG mitigation options. Assigning a high price on CO_2 emissions, establishing mechanisms for public support for Research and Development activities (R&D) and creating a predictable environment for investment constitute the primary factors assessed. In addition to being understood as applicable policy tools, economic framework conditions also regards costs of infrastructure and technology deployment as a function of technological learning. Political framework conditions focus on the willingness to combat drivers of climate change, towards CCS as a viable emissions reduction option, and the willingness to manipulate economic conditions to help commercialize the concept.

In addition to developing a model aimed at the political, economic and technological conditions for CCS in a climate policy context, chapter 3 also explains the concept of system boundaries and their relevancy when evaluating CCS as a policy instrument within a given context. Here the limiting factors time perspective, geographical scope, and technical and political levels of analysis come into play. Where system boundaries are defined, influences to what extent CCS qualifies as climate policy instrument.

Having built an analytical foundation to evaluate a case specific setting, chapter 4 starts off by introducing the empirical background of the Norwegian CCS effort as found by previous literature. Relevant Norwegian climate policy goals and obligations are thereafter elaborated upon, with emphasis given their functions as part of the sustainable development strategy. The chapter thereafter presents three different applications of the Norwegian CCS commitment. One scenario pertains the Mongstad full-scale project. The second addresses the TCM, while the final scenario looks at ambition of a commercialized European CCS network. The different scenarios operationalize different system borders, which in turn shed light on relevant aspects of the current and prospective Norwegian CCS effort.

Chapter 5 is the final analysis, juxtaposing the three scenarios outlined in relation to the main research question. This chapter evaluates the degree to which the empirical case, the Norwegian CCS effort operationalized in the three scenarios, can be understood as a "climate policy instrument." The main findings suggest that CCS has potential as a climate policy instrument primarily as an *end of pipe solution* in a single emission site perspective. In a wider system perspective, where electricity from CCS-equipped power plants substitutes more polluting alternatives, CCS may also be regarded a *transitional measure.* CCS in not sustainable, however, as it merely provides a technological fix to an environmental problem caused by exploitation of a finite resource. The decisive question as to whether CCS can function as a transitional step towards sustainable development, is whether fossil fuels inevitably will remain the main energy sources of industrialized societies in the coming decades.

Application of CCS in a Norwegian context requires significant directed public support to allow necessary technological innovation and infrastructure construction. In Norway, CCS as a climate policy tool arrives too late to contribute to achieve the set emission targets before 2030. I also question the extent to which CCS contributes to the national sustainable development strategy, finding CCS as policy behavior to inadequately reflect this policy intention. I suggest that the measure used to evaluate climate policy developments, based on the Kyoto target alone, is insufficient to measure sustainable development achievement. As executed policies are results of winning coalitions, it is relecvant to recall the two conditions for CCS to make sense in a climate policy perspective: a) continued fossil fuel consumption and b) GHG emissions reduction.

Chapter 6 concludes the text, where a short summary first is presented. Some central methodological issues are thereafter brought to attention. A few concluding remarks find their place in the very end. Hopefully, this study contributes to organize and lay the foundation for a more precise approach to discussing CCS as a climate policy instrument in Norway and beyond. Further knowledge is needed both in terms of more concrete scenarios and quantitative studies to shed light on the individual issues identified in this text. Now, chapter 2 kicks off the exploration towards a definition of the climate policy instrument concept

2. Climate Policy Instruments: Towards an Operationalized Concept

This chapter suggests what is a "climate policy instrument." Using theory on climate policy strategies and environmental management as points of departure, the chapter defines climate policy instruments, as measures and strategies, along with a reasoned typology. First of all, the following section frames the problem of human induced climate change to offer an understanding of how CCS could fit in this regard.

2.1 Framing Climate Change

Human induced climate change refers to releases of GHGs from human activities that are understood to cause the problem. In 2004, three main categories of emissions sources were responsible for 90% of all human produced emissions: Carbon dioxide (CO_2) from fossil fuel combustion accounted for 57% of emissions. Other fossil fuel combustion accounted for 16% of overall emissions. CO_2 released from deforestation was responsible for 17%. Methane and nitrogen off-streams from agriculture and energy consumption had a 22% share. Sector wise, power generation and industry are the most important sectors of the global economy representing 26% and 19% shares of total anthropogenic GHG emissions respectively (Metz et al. 2007).

Under the international climate change regime, the potential damage from emitting a given quantity of a GHG to the atmosphere, the Global Warming Potential (GWP) of the release, is determined by converting the GHG's GWP into CO_2-equvivalents. The GWP-indicator is based on the gas' impact from staying 100 years in the atmosphere.[8] Table 1 lists the gases covered by the UNFCCC as GHGs and their GWP in CO_2-equvivalents. Although having the least GWP intensity per unit, CO_2 is the most controversial gas because of its overwhelming share of emissions as presented above.

Table 1: Greenhouse Gases under the UNFCCC and their GWP*

Greenhouse gas		**GWP***
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrogen dioxide	N_2O	310
Hydrofluorocarbons	HFCs	100-12000
Perfluorocarbons	PFCs	6500-9200
Sulfur hexafluoride SF_6		23900

* Global Warming Potential

1 unit CH_4 "equals" 21 CO_2-equvivalents in a 100-years perspective.
(IPCC (2001c) in Stowell (2005: 5))

The IPCC describes climate change as "profoundly different from most other environmental problems with which humanity has grappled," pointing to its features as a public goods issue requiring collective action, the need for engaging diverse decision makers on all levels, the diverse characteristics of its causes and its global consequences (IPCC 2001d: 66). Indeed, climate change can hardly be understood in a single cause-solution perspective. While acid rain is avoided by cleaning NO_x and SO_x components from industrial off -streams, climate change mitigation requires more fundamental change. Certainly, both its causes and possible solutions touch upon the basic metabolism of industrialized societies – how resources are spent and processed. Chasek, Downie et al (2010) frames climate change as a "global environmental issue

[8] Assessing the damage potential from GHG emissions using the GWP-indicator has been subject to criticism as it is argued to
measure GHG gases' relation to *temperature increase*. For instance Shine, Fugelstvedt et al. (2003) propose a different methodology based on other criteria. GWP remains, however, the indicator of choice in the international climate change regime.

prototype" demanding collective action across sectors and on a variety of levels to combat it.

It should therefore not be surprising that the strategies chosen to encounter climate change have the potential to affect the strategic development pathways of societies. Steps taken to mitigate climate change may revise seemingly fundamental conducts of economic activity and value chains. Measures taken to limit climate change will therefore contribute to determine what future societies will look like. The following section looks into climate policies.

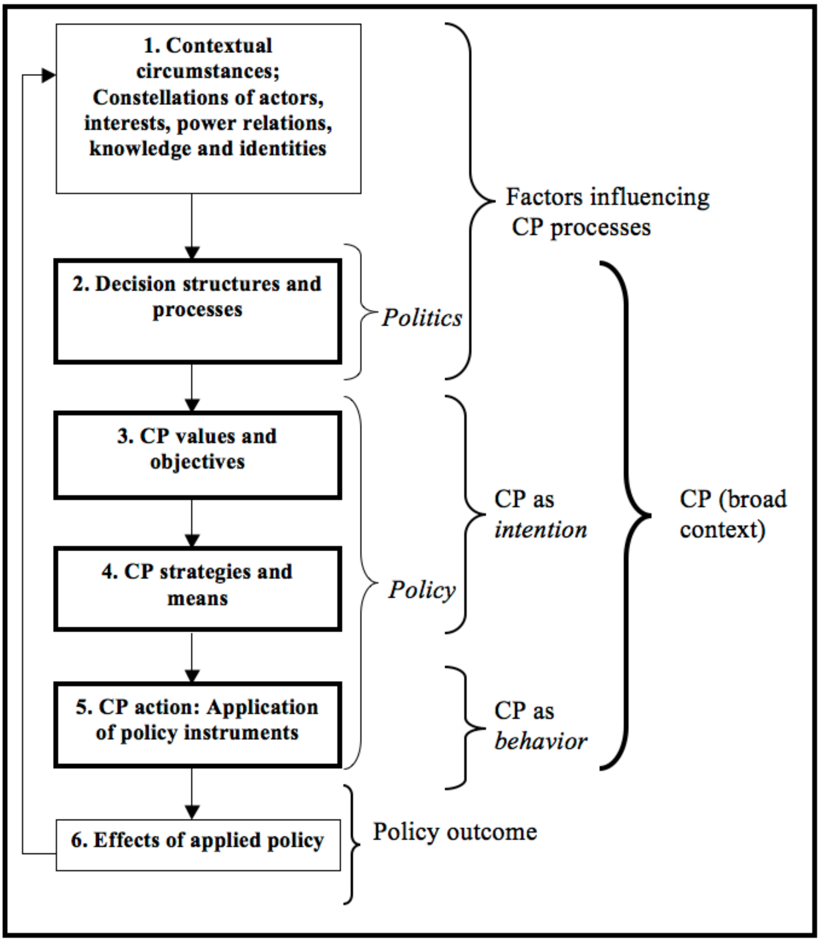
2.2 Climate Policy Identified

The term *policy* aims at the substantial *content* of political decisions, pointing at its characteristics like the choice *means* to achieve set *targets* - the selection of policy *tools* and *instruments* to fulfill political objectives. Political decisions to guide policies, result from *politics,* which are understood as the interaction among constellations of actors and interests within a decision-making structure and process (or lack of such) (Fermann 2001: 193).

Climate policy *measures* are in this text understood as substantive action taken to manage GHG emissions – like switching fuel types in a production system, improving energy efficiency by applying restrictive policies or investing in insulation products, or even deciding to build a CO_2 capture facility at a fossil power plant. More broadly, the term climate *policy instruments* also include manipulating strategic macro scale system structures, like changing political, economic, and technical framework conditions to sanction certain behavior among actors affected by the policy. Relevant framework conditions in a Norwegian CCS perspective are elaborated on in chapter 3.

Figure 1 outlines a model to overview the generic process leading to applied climate policy as described above. This illustration is borrowed and modified from a study of political space of maneuvering in foreign policy. It demonstrates how policy outcomes follow from politics and policy objectives, decided within a structure that limits the means available (Fermann 2010: 34). Although presented as a system where executed policies have feedback effects on the "contextual circumstances" for new policy decision, the present model represents a rather linear understanding of the policy cycle. An environmental policy process rarely follows these stages chronologically (Vig and Kraft 2009). This model serves, however, to demonstrate how a policy intention may be independent from the policy behavior and outcome.

Figure 1: Generic decision and implementation chain of Climate Policy (CP)

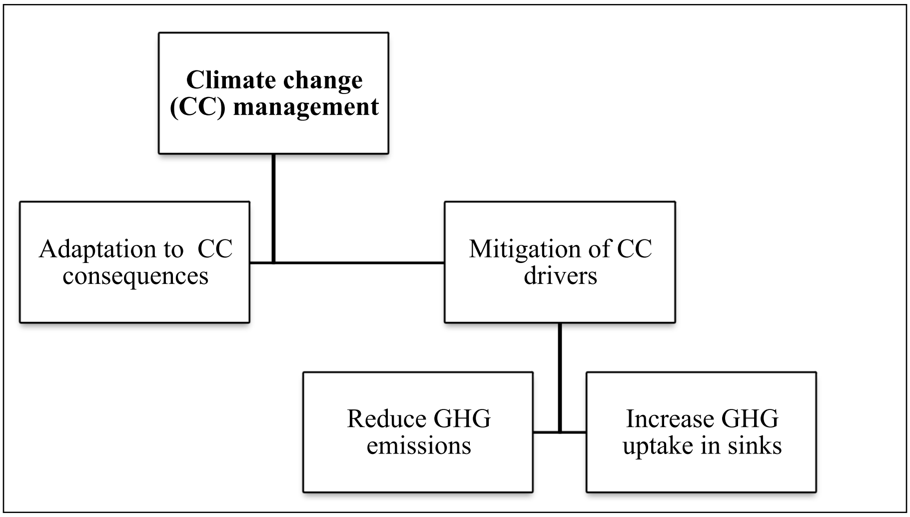


In a political context, where an aim is to create winning coalitions by aligning interests and actors, also successful climate policy measures strive to fulfill other objectives in addition to the climate change agenda: the more interests served, the larger coalition can be mobilized. Here so-called “no regret measures” are the lowest hanging fruit, an example being emission-reducing measures that come at practically no cost and which also benefit other interests. Yet, the main motive for climate policy measures should be to limit GHG releases (IPCC 2001b: 122).

If challenging to tell apart in practice, and some might argue of only academic relevancy, distinguishing climate policies from non-climate policies is crucial when understanding the underlying motives behind an action – what is motivated by environmental concerns and what is presented as climate policies but in reality serves other interests. This distinction is also relevant when developing GHG scenarios where it is necessary to foresee what emissions reduction measures will be taken with and without further incentives.

Managing human induced climate change can either relate to *adaptation* to its consequences or *mitigation* of its causes - namely reducing releases of GHGs to the atmosphere (Verbruggen 2007). Yet both types of action are important and necessary, this text deals with the latter aspect – from now on referred to as climate policy mitigation measures or in similar wordings. Such policies or measures contribute to (i) reduce GHG streams from emission sources like combustion engines, households, industrial sites, cities, countries and other systems *or* (ii) increase the uptake of GHGs in natural or artificial sinks (like forests), as figure 2 illustrates (Metz et al. 2007). From now on I focus on climate change emissions reduction mitigation strategies.

Figure 2: Different approaches to climate change (CC) management



Although both may lead to lowered CO_2-emissions, the literature distinguishes between climate policies and non-climate policies. A climate policy strategy is taken with the primary objective of lowering GHG releases to the atmosphere. Non-climate policies might have the same effect in terms of GHG emissions but are taken due to other reasons. This has for example been demonstrated by the virtual stabilization of Japanese energy-related CO_2 emissions from 1973 to 1986 prior to the introduction of an expressed Japanese climate change policy (Fermann 1995).

Metz et al. (2007) find that climate change mitigation activities should reduce GHG emissions by a) changing behavioral patterns, b) developing and implementing new technologies, c) capturing GHGs before they are emitted to the atmosphere or by d) enhancing natural sinks to sequester more GHGs.

Stern (2007: 214-215) argues that a climate policy measure may have either of two fundamental objectives:

- To reduce emissions from non-fossil fuel based sources:
  - Reduction of emissions from land use change, agriculture or fugitive processes.[9]
- To reduce emissions from fossil fuel combustion by:
  - Reducing demand for emission-intensive goods and services
  - Improving energy efficiency - fewer input, more output
  - Switching to technologies which produce fewer emissions and lower the carbon intensity of production

The Klimakur 2020 report (Klif 2010a) examines possible climate policy measures in a Norwegian context. This report bases its inquiry on achieving the previously mentioned Norwegian governments 2020 target, by cutting GHG emissions by 15-17 million tons CO_2-equvivalents in 2020 as compared to a Business As Usual (BAU) baseline scenario. [10] A host of mitigation activities are presented along two types of analyses. Both sector wise approaches to substantial actions (like improvement of industrial process, switching to new fuels) and possible effects from manipulating macro economic framework conditions through taxation and subsidies are assessed in various action menus or scenarios.

Still, also when taking this background into account, defining climate policy instruments merely as "deliberate" actions, as Stern's 1) or 2) or IPCC's a)-d), leading to lower GHG emissions than a Business As Usual scenario (BAU) is imprecise. I emphasize the importance of maintaining consistency between strategic ambitions and conducted policy instruments, which when turning back to figure 1 refers to harmonizing climate policy as *behavior* and climate policy as *intention*. In this regard, BAU scenarios may constitute a weak comparative basis for assessing behavior-intention-compliance or *means-goal efficiency* in climate policy *outcomes*. The more ambitious the strategic policy objectives are, the

[9] Fugitive emissions refer to leakages or unintended emissions from for example industrial activities.
[10] Norwegian climate policy targets are discussed further in chapter 4.

higher the risk becomes of loosing the link between policy intention and behavior in cases where policy outcomes are compared to a BAU reference only. This goes in particular where a policy field serves an overarching ambition, as is the case for climate policy – which in Norwegian policy making serves to underpin the sustainable development strategy.

The relationship between climate change and sustainable development has been identified as follows: "Decision making related to climate change is a crucial aspect of making decisions about sustainable development, simply because climate change is one of the most important symptoms of "unsustainability"" (IPCC 2001a). The statement suggests that current GHG emissions are one of several drivers of an unsustainable development. New questions now arise. What is sustainable development and how does it relate to climate change in particular? What does reducing GHG emissions imply in this regard? What kind of actions do such activities require? What is the *ideal* climate policy instrument? The following sections address these questions. In the following section, the evolution of strategies of environmental management and the link to sustainable development is accounted for.

2.3 Environmental Management: From Dilution to Sustainable Development

This section explores partly competing approaches to environmental management and their focal areas in search of answers to the questions above.

Attitudes and approaches towards pollution control have changed since the early beginnings of environmental management in industry and public administration (Dryzek 2005). Following the publication of Carson's *Silent Spring* (1962) and the initial recognition of pollutants' impact on natural surroundings in the early 1960s, attention was given dispersion and *dilution* of waste streams. Measures like building taller smoke stacks reflected the response taken to “water out” local environmental impacts from industry.

In the 1970s, *end-of-pipe-solutions* became the strategy. After recognizing that human activities could affect ecosystems, it became evident that unaccounted pollution streams had to be limited. From then on pollutants from industry were isolated and kept separate from the natural environment. Emphasis was put on avoiding pollutants to spread, while production processes remained the same (Brattebø, Røine et al. 2007b).

The following decade saw a shift towards recycling waste streams from production processes. This strategy has been named *recycling and recovery* (Strømman 2009) and focused on generating smaller waste piles by exploiting scarce resources more intelligently, in particular by recycling and recovering waste materials and spill energy. Approaching the 1990s, strategies labeled *cleaner production* and *ecological modernization* gained momentum (Brattebø et al. 2007b). If one found ways of delivering the same good by spending fewer resources it would benefit both economy and ecology, the argument went (Welford 1998). Not only resources spent during production or consumption were taken into account when assessing the environmental impact of products, services and systems, but also the whole life cycle or value chain. Strategies presented until this point were of a prosaic and *problem-solving* nature in contrast to approaches inspired by a more *imaginative* view on improving human activities’ impact on the environment (Dryzek 2005).

If still reformist but more ambitious, the *sustainable development* agenda is understood both as a normative “guiding concept” - a vision as an ideal state for human systems on all scales – and a context dependent operationalized objective (Steger, Achterberg et al. 2005: 25-26). Originally defined as a development that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987) by the so-called Brundtland commission, the academic literature now includes more than 200 definitions of the concept (Steger et al. 2005). Sustainable development is understood as holistic policy path, interlinking social, economic and environmental aspects as its fundamental pillars. It suggests that political liberties, livelihoods and environmental considerations are equally essential to achieve *sustainable development.* The concept refers to both intra- and intergenerational considerations. It addresses the north-south dimension of sustainability as related to resource consumption and equity issues among those currently inhabiting the planet. It also pertains intergenerational aspects related to the time horizon of resource management. Generating lasting growth on sustainable terms are key priorities of sustainable development (WCED 1987). Prescribing economic growth and environmental integrity to go hand in hand under the right social, environmental and economic conditions, sustainable development is embraced by decision makers at all levels as the desired course of development, spanning from local villages to the international community as a whole. (Metz et al. 2007, Welford 1998).

Operationalizing sustainable development in terms of substantial content is context dependent and debated. Although the vision of sustainability is shared as a state where economic activities grow within the carrying capacity of natural and human systems, the means of getting there are contested. *Industrial ecology* as a strategy to environmental management builds on the sustainable development ambition as a directed attempt to fill the concept with contents (Brattebø, Røine et al. 2007a). Interested in understanding the drivers of resource consumption, the approach prescribes wider system perspectives, broader environmental impact assessments and learning from natural ecosystems as key. The ambition is to “close the loops” of material metabolism in society in order to generate as few waste piles as possible. Industrial ecology evaluates human activities by focusing on resource throughput across value chains. Emphasis is put on providing services rather than particular products to perform them won attention: Creative solutions on getting a person from A to B were emphasized over the necessity of developing cars. A further realization that even global ecosystems suffered degradation from human activities led to a more thorough recognition of the need to exploit natural resources within their carrying capacity. This position was strengthened by an increased understanding of human systems as part of, and heavily dependent on, natural ecosystems (MEA 2005). This underpinned the necessity of finding alternative ways of generating human welfare in terms of services and products. A decade into the 21st century, industrial ecology is understood as the main strategic tool in societal planning to achieve sustainable development.

Looking at approaches towards achieving the UNFCCC ambition of stabilizing GHG emissions, Young (2010: 94-95) describes two competing perceptions: The North-American climate change mitigation strategy, he suggests, is aimed at "simply" controlling GHG levels in the atmosphere. One could argue that this approach has most in common with the early problem-solving environmental strategies presented above. The author further suggests a second, supposedly European, approach towards GHG mitigation that emphasizes decarbonization of industrial societies and changing how human activities are conducted. This latter course has more in common with the sustainable development agenda.

Also when evaluating the environmental benefits of technological innovations, it may be challenging to determine an instrument's "shade of green." *Technology of transition* is a term used by Rejoy (2009). He describes technologies that are not considered sustainable on their own, but with improved climate and resource related footprints compared to Business As Usual (BAU) solutions. These transition solutions are necessary beginning steps before real sustainable solutions can be deployed, the author argues. He points at phasing in natural gas at the expense of coal power as an example of such. The next section looks at technological innovation and diffusion as climate policy contributions. Recognizing sustainable development as the ambition to strive for, section 2.4 discusses the role of technical innovation in improving the carbon footprint of industrial activities.

2.4 Innovation Towards Technological Change: Sustainable Development at Work?

New technology may enable production of goods and services with lower GHG emissions and technological innovation will prove crucial to ease drivers of human induced climate change (Steger et al. 2005). Being the backbone of modern economic activities, and given its current and projected share of human GHG releases, mitigating emissions from *human energy systems* will in particular be necessary to combat climate change (Smil 2003). It is argued that innovation in energy technology will be the solution to achieve this, also when taking projected efficiency improvements into account (IEA 2010c). Also the case for CCS technology development is made following this rationale, of course (GCCSI 2010).

Innovation takes place over the following stages; R&D, invention, market introduction, and diffusion (Steger et al. 2005: 35). *Technological change* takes place when new technology phases out and substitutes existing technology. Freeman and Perez (1988 in Martinsen 2010: 20) categorize levels of technological change from weak to strong as either *incremental improvements*, *radical innovations*, *technology system change* or even techno-economic paradigm change affecting the whole economy.

Following the understanding of climate policy measures as established in section 2.2, heavily industrialized sectors – like the energy sector – will, to a large extent, rely on new technology in order to mitigate its carbon emissions (Smil 2003). Technological change and innovation is therefore crucial aspects of the climate policy toolbox for the energy sector.

Since different public policies may foster different types of innovation and technologies to be commercialized, innovation policies are essential when setting the long-term technological course of society. Innovation policies have been explored by literature on links between industry and governments' reliance on certain industrial complexes (Moe 2007). Directed policy measures in support of existing axes of innovation may cause a kind of *path dependency* that is suboptimal for society overall, but which benefits the selected technology initiatives at the time. If government has perceived interests in prolonging the success of certain industries, such *vested interests* may lead to government policies that are not beneficial for society as a whole. In the longer run they may produce incentives undermining new innovations beyond the dominating techno-economic paradigm (Moe 2007; 2009).

Applied on the energy sector a parallel phenomenon is described as "carbon lock-in" (Unruh 2003). In such a state, previous investments in fossil fuel infrastructure and technology justify new investments in the same technological paradigm, leading to further carbon lock-in, even when all long-term scenarios prescribe the necessity of a technological shift away from fossil fuels.

In a narrower scope, Bye, Heggedal et al. (2009) argue how directed public funding of R&D for CCS technologies in Norway may lead to sub-optimal efficiency for society. The authors suggest that such artificial stimulus of a certain technology development, like the Norwegian CCS track, leads to overinvestment in this technology beyond what otherwise would happen, and thus draws resources away from competing technological innovations. If public R&D support for climate friendly energy technologies should be given to compensate underinvestment in this sector, it should rather be distributed flat among the different technologies so that the most efficient solutions get a chance to stand out. It may therefore be more efficient in an economic context to allow market mechanisms to pick winners at this stage of technical immaturity and not "manipulate" the innovation process by picking potentially sub-optimal winners, given that development of low-carbon technologies is the primary motive of the innovation policy. Various approaches to carbon pricing are typical market mechanisms where theory holds that the higher cost of emitting CO_2, the more innovation in low-carbon technologies takes place. This type of structural economic framework condition in a CCS perspective is discussed in chapter 3.3.

Proponents of CCS, on the other hand, point at the necessity of directed R&D support to accomplish the potential of CCS. Because CCS is immature and expensive at the moment, these technologies suffer from underinvestment that hinders CCS from competing in a market (IEA 2010b). Since society supposedly has much to gain from large-scale CCS deployment, policy makers must be willing to pick this winner and lift it forward for commercialization, they suggest (Ministry of Finance 2009a). In order to achieve this, the IEA finds that the best approach is to start off by developing necessary infrastructure and conducting early R&D activities. Steady technology specific funding to lower the cost gap towards other technology options should follow this first step. Directed support would thereafter decline as the technology approaches market maturity. From this stage on, general market barriers for environmental technology should be addressed so that a viable, predictable market for CCS and competing environmental energy technologies can develop (IEA 2010b).

What types of technological innovations to support in a climate policy perspective depend on the criteria chosen to evaluate them. Criteria for evaluating climate policy instruments is the topic of section 2.5.

2.5 Evaluating Climate Policy Instruments

Metz et al. (2007) note that little consensus is found in the literature on *criteria for evaluating* environmental policy instruments. Regardless, four main categories for benchmarking such policy measures are identified:

- *Environmental effectiveness* – the extent to which a policy meets its environmental objective.
- *Cost-effectiveness* – the societal cost to achieve the environmental objective.
- *Social distribution* – the social and equity aspects of policies and actions. This criterion is understood as inter- and intra generational aspects to sustainable development in this text.
- *Institutional feasibility* – the extent to which a policy or measure is viewed as legitimate and implementable within a certain context. Also considerations on *political* feasibility are included in this regard, which refer to constellations of interests and actors in the given context.

Vig and Kraft (2009) utilize similar categories in assessing environmental policy measures while also underlining *cost-benefit assessments'* contribution to the mix - and thereby assign value to measures that fulfill several interests, along with viewing time as a factor. We have already seen how Klimakur 2020 (Klif 2010a) puts *time* into the equation by focusing on measures with a mitigation effect before 2020. Stern (2007) and similar long term economic assessments of climate change costs operate with discount rates for estimating future costs and benefits: What are the costs and benefits of investing today as compared to waiting – say - fifteen years? Discount rates are guided by expected inflation, technological changes, changes in prices and other external factors, but are basically a qualified guess on future investment costs – as any future predictions.

The Official Norwegian Report 2006: 18, "A climate friendly Norway" (Ministry of the Environment 2006), presents additional criteria for evaluating climate policy instruments. The authors emphasize a few large, technologically oriented GHG mitigating solutions in a Norwegian context and point at their (i) *robustness* towards future trends and changes and their (ii) contribution towards *international technology development* in addition to several of the already mentioned aspects. As we shall see these two are particularly relevant in the Norwegian CCS context.

The various approaches to environmental management presented in section 2.3 have shown how different strategies focus on different system perceptions. End-of-pipe solutions handle generated flue gases, while an ecological industrial approach enters the process causing the emission and asks how the same service can be provided without generating pollution in the first place. Such process-oriented measures might be more costly in the short term, but could also be beneficial in the longer run. This connects with the above reference to discount rates and predicting future scenarios on climate change. Deciding whether to make large investments in changing the infrastructure causing the fundamental problem, or rather to provide a quick fix, is often not an obvious choice. Here, future scenarios and predictions play a large role for determining costs, benefits, consequences and opportunities.

In addition to system boundaries along a time axis, changing geographical scope is also worth including in this overview. Should the climate policy measured be local or global in scope? National registries under the international climate regime distinguish between national and foreign emissions. Is mitigating GHG emissions in country A from seizing a production facility a successful climate action if it leads to the opening of new production with equal or higher emissions in country B? "Yes" for country A and "no" for the planet? This phenomenon, called *carbon leakage*, is a valid concern that makes assessing and comparing climate policy measures an even more complex exercise (Verbruggen 2007: 811).

Furthermore, life cycle perspectives on environmental management have shown how solving one environmental impact can lead to new problems. In a climate change context can this type of *problem shifting* take shape as increased emissions somewhere else in the life cycle of a product or as leading to other types of emissions (Brattebø et al. 2007b: 2-39). A seemingly fuel efficient hybrid car might not be as environmentally friendly when it turns out that producing its battery causes unforeseen GHG or acid spills. Accounting for such problem shifts – deciding which new impacts that are acceptable and not – for climate policy measures are therefore another relevant aspect of a cost-benefit assessment. Environmental strategies adopting a broad *system focus*, like industrial ecology, take these considerations into account more often. More narrow-sighted end of pipe solutions do not account for potential problem shift to the same extent. The use of different system borders in this study is discussed further in chapter 3.5.

The above sections in this chapter have demonstrated that climate policy measures and non-climate policy measures can be understood as a dichotomy – at least on paper. It has also shown that distinguishing well performing from less satisfactory measures is not a question of black and white. The criteria used to assess climate policy measures determine their value. How this plays out on CCS in a Norwegian context will be discussed further in chapter 4. Based on findings in the previous sections of this chapter, typology for different types of climate policy instruments is suggested in section 2.6.

2.6 Climate Policy Instruments Operationalized

In Section 2.2 it was determined that a climate policy instrument is a policy primarily motivated by mitigating the drivers of anthropogenic climate change. As we have seen over the previous sections, considerations are many as to *what* goals and means such instruments should accommodate and *how* performance should be measured.

This section outlines a typology of climate policy measure following the various factors and criteria identified above. Spanning from "no climate policy" to "sustainable development," the following categorization aims at articulating different types of climate policy measures along a scale.

No such scale can be “objective.” Apart from the decisive “main goal served” criterion, the different criteria for evaluation are similarly weighted. However, I acknowledge developments in environmental management and understandings of human activities’ impact on the environment as they have been described in the previous sections. Following these trends, the sustainable development agenda leading to process and function oriented strategies, are regarded superior to transitional and end of pipe strategies. Particular emphasis is therefore put on categories that address these ambitions in the eventual analysis. Further, having noted how climate policy instruments may focus on behavioral patterns, enhancing sinks and reducing emissions from sources, this typology emphasizes a technological approach to the latter objective. This assigns technological innovation an important role. When pointing at “structures”, I refer to systemic economic and political structures in an institutional perspective like those that are described as political and economic framework conditions in a CCS context in chapter 3.

The policy instruments described within the various categories should be considered as conceptualized ideal-types and not watertight definitions. An actual climate policy instrument will in reality cross category borders. When using this typology, they are therefore best described in terms of their predominant attributes along the categories presented in table 2 below

Criteria for evaluation	Table 2: Technology oriented climate policy instrument categories			
	Non-climate policy	**End of pipe solutions**	**Transition solutions**	**Sustainable development**
Empirical examples	Replacements for CFCs in cooling systems CO_2-based EOR.	Exhaust gas treatment from industrial sites: NO_x and SO_x cleansing of smoke stacks	Packaging recycling. Replacing coal with natural gas as energy carrier	Long lasting renewable energy systems "Natural" bio-energy for heating
Strategy of inspiration	*No regret actions*	*End of pipe solutions*	*Cleaner production*	*Industrial Ecology*
Main goal served	Other than GHG abatement	GHG mitigation	GHG mitigation	GHG mitigation
Potential other goals served	Any, including GHG mitigation as a "no regret measure"	Cost-efficiency, other environmental impacts	Other environmental impacts, cost efficiency, lowered resource consumption	Other environmental impacts, cost efficiency, sustainable resource throughput
Cost-efficiency and time perspective on problem solving capacity	Varies	*Short term*: High as few structural changes are needed. Early GHG cuts over expensive systemic changes prioritized. *Long term*: Low because more profound system changes may be required in the future.	*Short term*: Varies, some structural changes needed. Attention given transitional solutions towards a greener society. *Long term*: Potentially high as some structural changes are taken	*Short term:* Potentially low, because expensive structural changes are needed. Long lasting change over low hanging fruits emphasized. *Long term*: Potentially high because beneficial structural changes take place
System focus	Varies	Single emission source or life cycle stage perspective	Improved sector or life cycle perspective	Complex system perspective towards both human and natural systems
Process and function orientation	Varies	*Limited* – processes and resource consumption remain the same to maintain low investment costs	*Some* – recycling and smart use of resources take place requiring some system change	*High* degree of functional orientation
Related technology change and contribution towards international technology development	Varies	*Incremental improvements* – limited technology development contribution from solutions based on known practice	*Radical innovations* – Significant technological development contribution following process oriented innovation	*Technology system change* - Potentially very valuable technological contribution if international trends shift towards sustainable development
Institutional and political feasibility	Feasible and common, especially since meeting other interests facilitates action	Feasible – The approach towards climate policy measures is often framed as a question of cost-efficiency in a short-term perspective. Only basic commitment towards climate policy required.	More demanding and more challenging, but still feasible because relatively low hanging fruits from cost efficiency gains following process improvement take place	Demanding to gain acceptance for investing in structural changes and shift towards a functional orientation – requires broad societal change beyond investments in technical innovation.

Having identified climate policy measures and their characteristics along the typology above, chapter 3 will now explore the framework conditions necessary for CCS in Norway to function as a climate policy instrument. This occurs along with an introduction to what the CCS concept comprises.

3. Framework Conditions and System Perspectives

This chapter introduces the framework conditions that together constitute the model upon which data will be constructed and analyzed for evaluating the Norwegian CCS context in a climate policy perspective. Here each of the framework conditions for evaluating CCS as a climate policy measure are examined and specified; namely technical, economic and political framework conditions for application of CCS as a climate policy instrument within a given system. My interest lies in understanding how well CCS can perform as a climate policy instrument given that the concept delivers as promised. This has led to the omission of the debate on leakage risks from CO_2 deposits and public acceptance in this text. This could be seen as controversial, especially when taking into account that these are factors that may limit CCS deployment in many national contexts – although this has not been contested issues in Norway (Greenpeace 2008, Stenhouse, Gale et al. 2009).

First, some basic characteristics of an integrated CCS value chain are presented in section 3.1. Section 3.2 thereafter establishes what is meant by *technical framework conditions* in this study. Section 3.3 outlines what are *economic framework conditions,* before section 3.4 takes a similar look at *political framework conditions*. Section 3.5 gives attention to other *system boundaries* in addressing CCS as a climate policy instrument. Such changing system parameters are eventually discussed within three empirical scenarios presented in chapter 4. Having built this framework of analysis, chapter 4 is ready to encounter the Norwegian CCS context. First, section 3.1 gives an overview of the CCS concept and its different stages.

3.1 Carbon Capture and Storage: Introducing the Concept

CCS is often presented as one concept or one measure. In reality it consists of several processes requiring advanced integration of different technologies that traditionally have been applied independently and in smaller settings. CCS can potentially be used in contexts with emissions from large point sources, mobile and smaller fixed sources, biomass combustion and direct capture from air (Meadowcroft and Langhelle 2009a). Currently, CCS from large point sources is what occupies the agenda in any country.

Up to 77 large-scale integrated CCS projects are in various stages of development globally. Of these, 42 are related to thermal power generation. The remaining projects address various types of industrial production (GCCSI 2011).[11] Not more than 5 commercial scale CCS plants are operational today (Ministry of Petroleum and Energy 2010b)

An integrated CCS project spans across four stages: CO_2 capture, transportation, storage, and monitoring of the CO_2 deposit. The different processes of an integrated CCS project are presented in the following. For a more detailed introduction to the technical aspects of these activities see for example Nichols (2007).

CO_2 can be captured from gasified fuel before (pre) combustion or from the exhaust gas after (post) combustion. This has led to three technology tracks in CO_2 capture, labeled "pre-combustion", "oxy fuel" (which is

[11] A large-scale project captures and stores at least 80% of 1 million tons per annum (Mtpa) of CO_2 from coal power generation or similarly at least 80% of 0.5 Mtpa of CO_2 from other emission intensive industrial facilities (like natural gas power generation) according to the GCCSI and G8 criteria (GSSCI 2011).

pre-combustion in an oxygen rich environment) and “post-combustion”. Post-combustion is arguably the most mature of these approaches, typically using a technique of absorption and desorption with amines to separate CO_2 from the exhaust flow (Gibbins and Chalmers 2008). “Full CO_2 cleansing” using post-combustion technology captures 85-95% of the CO_2-content in the flue gas (Ministry of the Environment 2006). Only post-combustion capture systems can be retrofitted into existing emission sources (Forsyth 2007).

In 2011, capture technology demonstration and pilot centers have been built or are under construction in countries like UK, France, Spain, Germany, Norway, USA, Canada, Australia and China (GCCSI 2011). Post-combustion is the technology of choice in 29 large-scale CCS projects in the pipeline, while 21 projects expect using pre-combustion technology. The latter solution has higher potential in terms of energy efficiency and capture rates in combination with lower capital costs when integrated into new industrial plants, but is not as widespread as its exhaust based competitor (Blomen, Hendriks et al. 2009). “Oxy fuel” combustion is designed for pulverized coal fed combustion and is the cleanest of the three, leaving few off-streams other than hydrogen and water.

A natural gas fed CHP has an energy efficiency of <60% at best. Fitting a CO_2 capture plant would lead to at 10-30% decrease in efficiency, which is a significant loss (Ministry of Petroleum and Energy 2010b: 27, Ministry of the Environment 2006: 87). This *energy penalty* should come down to <8% over the coming decade, analyses suggest, in order to improve the competitiveness of the technology (IEA 2008). Depending on assumptions, a CO_2 capture plant would currently cost 70-80% of the complete CCS chain (Blomen et al. 2009). Additional main cost barriers for CCS capture technology include learning to *scale up* the process for industrial use and *integrating* capture systems with the other processes at industrial plants (IEA 2008).

In stage two of a CCS chain, CO_2 is compressed and transported to a deposit. Also these processes require additional energy. The gas is compressed to its super critical phase to where it has certain liquid and gaseous characteristics. Transportation may happen by pipeline or ship (ElementEnergy 2010). Currently only smaller CO_2 vessels have been built, though designs for larger ships ready are for production if demanded (CCJ 2010). Commercial scale pipelines for CO_2 transportation have been used in North America for three decades (Ministry of Petroleum and Energy 2010b). As few value chains for CO_2 are developed, demand for this infrastructure has not been overwhelming to date. Expecting an upswing, governments and industry are currently developing requirements and standards for CO_2 transportation (IEA 2010a).

The process of preparing suitable CO_2 depots might arguably be *the* main factor to slow down global CCS deployment (Kaldi 2010). While a capture plant can be built in few years, thorough storage site characterization may take up to ten years (GCCSI 2011). Ensuring that CO_2 will remain in its deposit at satisfactory risk requires detailed examination before injection and monitoring during and after. In a climate change context it is particularly important to ensure that the CO_2 stays in place; preferably indefinitely or at least for so many hundred years that anthropogenic CO_2 emissions are within safe thresholds when leaks happen (Aarnes, Selmer-Olsen et al. 2009). The long time perspective necessary in CO_2-storage operations fuels concerns among CCS skeptics.

Saline aquifers and stable geological formations as described above are considered viable CO_2 storage options (Ministry of Petroleum and Energy 2010b). Also deep sea open water CO_2 injection was as late as 2005 regarded safe, but has since been discarded due to increased ocean acidification from high CO_2 concentrations (Metz et al. 2005). Potential CO_2 deposits are found where layers of solid rock shelter layers of sedimentary porous rock types. CO_2 is injected under pressure at 600-3000m below sea level into the porous stone and kept from escaping by the cap above. This increases pressure in the reservoir. Using Enhanced Oil, Gas or Methane Bed Recovery (EOR; EGR; EMBR- hereafter referred to as EOR) techniques in oil and gas fields respectively, one may take advantage of this pressure increase to extract more fossil fuels. CO_2 is well suited as pressure support and is used in onshore EOR operations in North America (Finley 2010, Ministry of Petroleum and Energy 2010b).

Against this backdrop, aimed at illustrating main aspects of the different stages in integrated CCS projects, the following sections present framework conditions necessary for assessing CCS projects as climate policy instruments.

3.2 Technical Framework Conditions

I assume a parsimonious approach to *technical framework conditions* for *CCS* as a climate policy tool. The primary factors evaluated include the technical *performance* of capture technologies in terms of problem solving capacity and cost. More thorough technical assessment than what is found in this study, would probably address specific challenges related to post-combustion technologies or energy costs of compression processes. It would also discuss challenges related to finding standardized deposit site monitoring techniques (Aarnes et al. 2009).

CO_2 avoided is a key measure to evaluate the GWP of a technical system. Recent life cycle assessments (LCA) find that thermal power plants equipped with integrated CCS systems achieve 64-78% reduced GWP when compared to plants without CCS. Actual reductions depend on capture technology choices and fuel input. The CO_2 content in exhaust from coal combustion is 14% as compared to 7% from natural gas. Net CO_2 avoided is therefore higher in cases with CCS equipped coal-fueled systems than natural gas based plants (Singh 2011). The CO_2 avoided component takes into account the cleansing rate of the capture system, energy intensity in facilities and infrastructure production and operation throughout its lifetime. The scenarios used assume storage in geological formations with very limited leakages (ibid.). For instance the IPCC (Metz et al. 2005) assigns CCS plants with lower GHG mitigation potential than other studies. In many cases this is because the IPCC

report accounts for the whole CCS chain using the *CO_2 avoided* measure, while the others look at the capture stage of the value chain only.[12] Previous assessments of the environmental performance of CCS plants in Norway focusing on the capture stage alone, like The Ministry of the Environment (2006: 89) and NVE (2005), have therefore accredited CCS systems as leading to 85-95% lower GHG emissions than a CHP without CCS installed.

Technological performance is further related to *problem shifts*. The maturity level of technical solutions can be evaluated by assessing what new problems they cause. This phenomenon has in the case of CCS been demonstrated with the amine problematique in post-capture technology and potential leakage risk from CO_2 storage sites.

The three main cost drivers for CO_2 capture technologies, namely the mentioned *energy penalty, scale-up* and *integration* challenges, are in this study combined in an indicator for the cost of capture technology (IEA 2010b).

Other framework conditions are understood to include available CO_2 storage sites as presented in the previous section. Routines for developing safe, mature and monitored deposits are fundamental requirements in this regard (also to improve the legitimacy of CCS as a climate policy instrument) (Ministry of Petroleum and Energy 2010b). Equally important is the existence of infrastructure for transportation. In addition are sufficient amounts of CO_2 crucial for a functioning CCS value chain, of course. Particularly in an EOR context is a stable flow of accessible CO_2 necessary in order to apply pressure support (ElementEnergy 2010).

Finally, prospects of technological learning both in terms of improved technical utility and cost-efficiency are considered in this study. Table 3 summarizes the mentioned technical framework conditions considered in this study. Of note, none of these factors revolve around unsolved

[12] IPCC's findings correspond to Singh's (2010) results.

technical "mysteries" but focus on improvements in terms of efficiency, infrastructure construction and risk mitigation.

Table 3 aggregates and divides the different technical framework conditions as has be described in the above.

Table 3: Technical framework conditions

	Main factors related	Specifications
Capture	Technology costs	Energy cost Integration issues Scale up challenges
	Technology performance	CO_2 avoided Problem shifts
Transportation	CO_2 availability Infrastructure availability Operational regulations exist	
Storage	Storage sites characterized and prepared Injection and monitoring techniques exist Operational regulations exist	

Having established what technical conditions are necessary to highlight in the following analysis, the next section elaborates on what is meant by economic framework conditions in this text.

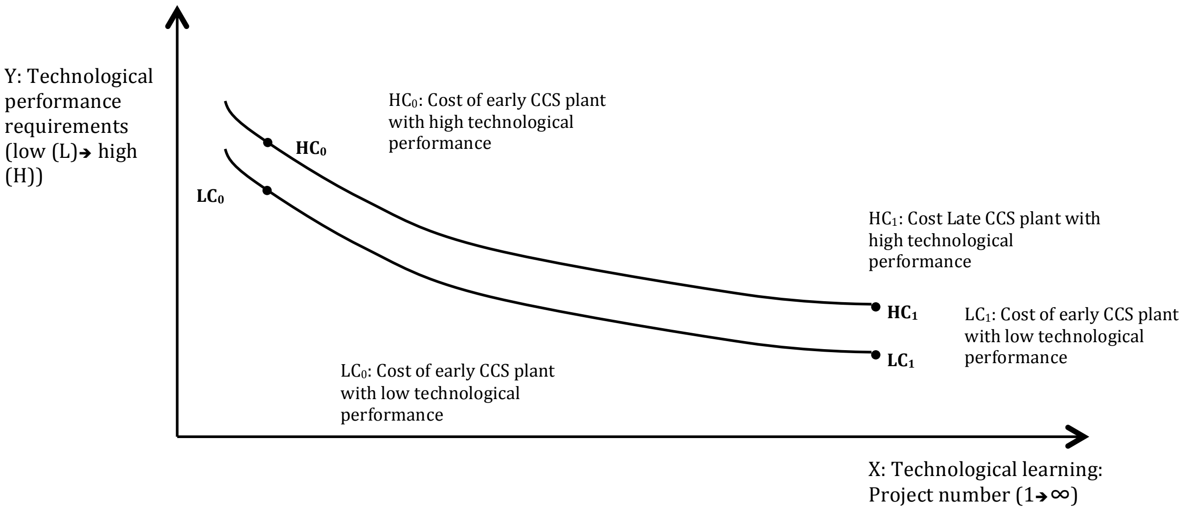
3.3 Economic Framework Conditions

Implementing CCS has a cost, both in absolute terms and relative to other climate policy instruments. The size and relationship between these cost drivers, which ultimately determine the price of CCS as a climate policy instrument, are defined by what is considered economic framework conditions for deploying full-scale CCS plants in a market. This section establishes the cost factors considered in a *public policy* perspective in this study.

First, in a climate change context, the cost of CCS will be compared to other policy options, like doing nothing to mitigate climate change or doing something else - like buying emissions quotas abroad, investing in offshore windmill technology or improving process or grid efficiency. Different climate change projections predict different costs of doing nothing to limit of climate change (Parry, Canziani et al. 2007, Stern 2007). Different policy frameworks and circumstances allocate different costs to different mitigation options (Metz et al. 2007). The costs of these factors are not explored in quantitative terms this study. Their function, however, as a backdrop for comparing costs of CCS as a climate policy tool is recognized.

Second, in addition to the relative costs, CCS deployment has a price in absolute terms following capital investments and operative costs in the use phase. Monetary estimates for “generic commercialized CCS” vary from IPCC’s estimated USD 17-75 per ton avoided (Metz et al. 2005) to Al-Juaied and Whitmore’s USD 120-180 CO_2 per ton from an early “first of its kind” plant (2009). In a European context it is argued that a CO_2 price around USD 75 would be necessary to spark CCS projects in the energy sector (Greaker 2011). In Norway, Klimakur 2020 (Klif 2010a) finds that a ton of captured CO_2 will cost NOK 1300- 2250. The CO_2 avoided cost vary with technical system assumptions and whether the project is the first or the “n’th” of its kind (Campbell 2008). First mover costs are higher because *technological learning* from operative experience and continued R&D facilitate improved and standardized solutions that makes technology less expensive (Martinsen 2010). Figure 3 illustrates conceptually how costs might decrease as a consequence of lower performance requirements and improved technological learning. The higher technological performance requirements in terms of capture rate in particular, the higher costs (Hildebrand 2009). Absolute costs of CCS deployment also depend on the emissions source type. Retrofitting a CCS system into an existing complex industrial plant is more expensive. Integrating a capture plant when constructing a new coal power plant is less cost intensive (Greaker 2011).

Figure 3: Absolute costs of CCS systems (C) as a function of technological learning (x) and technological performance requirements (y): C= F(x,y)



Economic framework conditions for CCS deployment are further dependent on the long-term investment climate for CCS projects. For CCS, as for other new industry and technology, predictable, beneficial public support mechanisms are important factors for developing an environment for investment (IEA 2010b). Such incentivizing measures could include loan guarantees, tax breaks, public project ownership and direct subsidies. When there is no established market, policy tools that could generate incentives for technology commercialization are vital – this includes providing demand for the commodity if necessary.

Attention is given to the political economy of public policies in this study. Equally important is that the governments' effort to commercialize this technology partners with industry that have the capacity to accomplish this type of projects. Industrial actors must have the technical know-how, project management skills and be willing to take the considerable risk involved with doing full-scale CCS.[13] Large-scale companies typically possess this robustness. This narrows the number of potential private partners significantly in many national contexts.

[13] Courtesy of an interviewee

All studies on implementing CCS in particular and on climate policy measures in general underline the necessity of making climate policy cost-efficient: that is assigning CO_2 emissions a higher cost than applying GHG mitigation measures. This requires also increasing the price on CO_2 emissions, not only lowering the price on solutions. This is usually done using environmental performance requirements, imposing a direct tax on CO_2 or via quota markets. Under such a regime, sale of CO_2 storage capacity could also be a relevant source of income to balance the cost-revenue equation. Adopting a long-term high price on CO_2 is considered the main objective in making CCS cost-efficient and creating a predictable investment climate (IEA 2008). CCS proponents find inspiration in the Norwegian Sleipner and Snøhvit projects where a tax on CO_2 was enough to prompt CO_2 separation and storage activities when the technological and political conditions were already in place.

Increasingly addressed in literature, CO_2 can also have a price as something else other than an unwanted byproduct. As mentioned, CO_2 may be used as pressure support in EOR operations. It may also be used for other industrial processes, as in concrete production or in food industries (Heyn 2011). Even if demand can never match the overwhelming supply following large-scale CCS deployment, these applications may give CO_2 monetary value as a productive commodity in applicable contexts.[14] Particularly in the case of EOR, however, would use of CO_2 require new infrastructure to be built for transportation and storage of CO_2. Yet, EOR is often presented as a necessary source of revenue from CO_2 capture to commercialize the concept in international energy policy scenarios (IEA 2010a). Table 4 lists the economic framework conditions presented in this section.

[14] This application of captured CO_2 is often referred to as Carbon Capture and Utilization (CCU) as opposed to Carbon Capture and Storage (CCS).

Table 4: Economic framework conditions

Costs of CCS compared to other climate policy alternatives:	Costs of other climate policy instruments CCS technology R&D and technology learning Technological performance requirements A predictable environment for investment
Costs of CCS compared to emitting CO_2:	The cost of CO_2 emissions Sale of CO2 as a useful commodity
Capable and risk willing industrial actors	

Having looked at factors for assessing the economic framework conditions for realizing CCS as a climate policy instrument, the following section looks into political framework conditions on different levels.

3.4 Political Framework Conditions

In substance, the technical and economic factors presented above will be shaped as results of deliberate policy paths (although one also might argue that technical and economic "realities" determine the political scope of action). Establishing public support mechanisms for CCS and deciding a general CO_2 price are examples of policy choices materialized in economic incentive structures. This section presents questions to be addressed by public policy on engaging CCS in a climate change context. Policy makers' response to these concerns, whether at the international or the national level, will in sum set the *political framework conditions for CCS* as climate policy. Strikingly, several of these normative issues intersect scientific climate and energy scenarios, societal development paths and, as always in policy making, allocation of scarce resources.

First, policy makers must decide if and how climate change requires action. Choosing to combat drivers of climate change requires political leadership in answering diverse questions (Metz et al. 2007). How ambitious GHG mitigation targets should be decided and in what time perspective should cuts happen? Considering national circumstances, in what sectors of the economy should cuts take place? Should emission cuts be taken domestically or abroad? Bearing findings from chapter 2 in mind, what type of climate policy measures should be given priority?

Second, is CCS an adequate climate policy instrument? Policy makers will have to decide whether CCS is needed and wanted. In addition to deciding to mitigate GHG emissions, this requires having confidence in particular energy and climate scenarios at the expense of other projections. These scenarios give answers to questions like; will fossil fuels be in as high of demand in thirty or fifty years? Will CO_2 emissions really have to peak over the next two decades in order to combat climate change? How early can renewable energy supply really start phasing out carbon intensive alternatives? If finding that fossil fuels will remain the main energy source also in the coming decades, a basic requirement for CCS support is met.

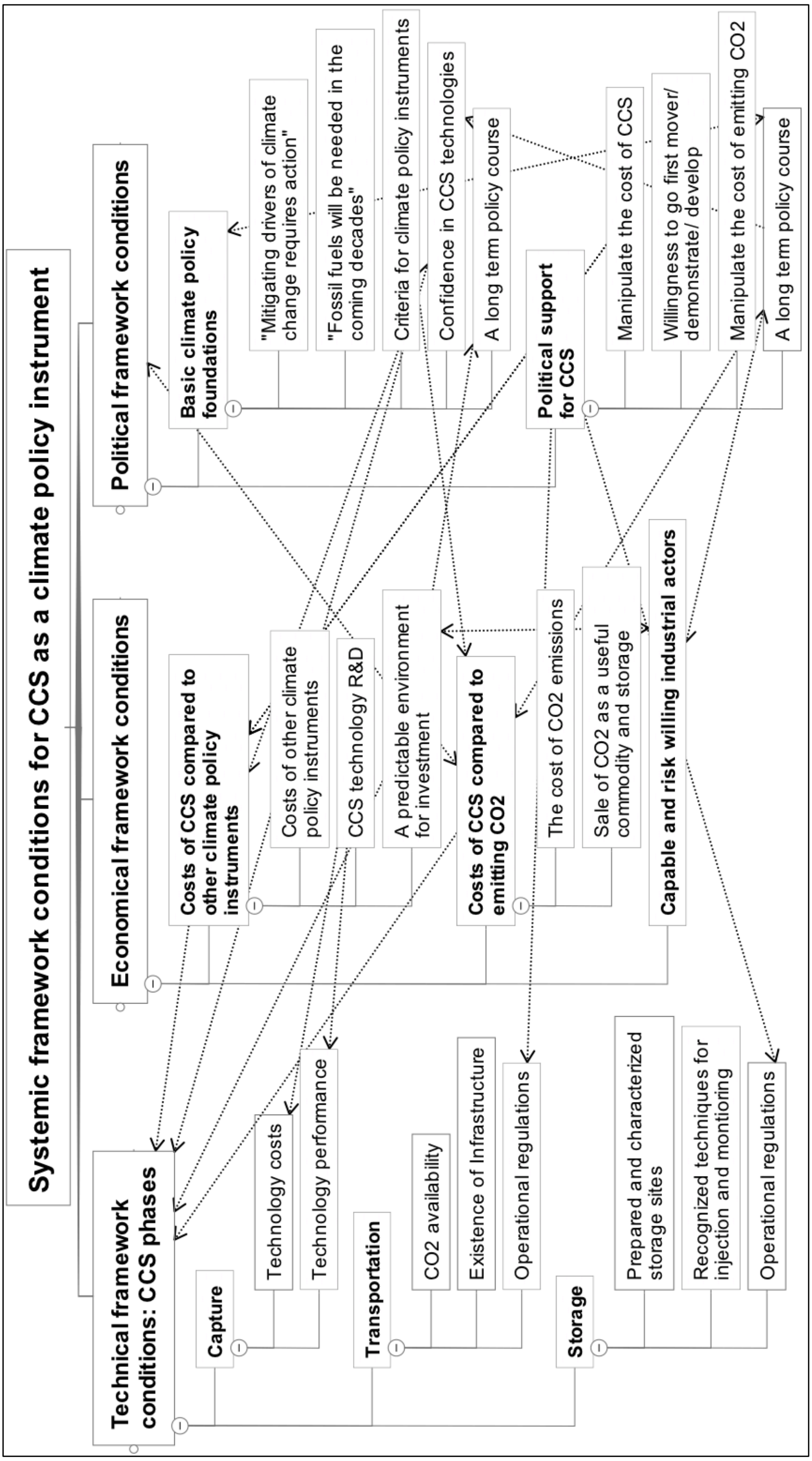
Having found that CCS is necessary, either to support long-term fossil energy production or as a transitional solution, other questions arise. What are acceptable costs for CCS technology? Is it important to be a CCS pioneer, or could one wait until the technology is standardized and less expensive? How should CCS R&D and investments be encouraged? Should governments give general tax breaks for any climate policy measures or, to the other extreme, specifically own and operate CCS plants? Should CCS be prioritized over other climate policy instruments and why?

In addition to answering these overarching questions, CCS implementation will also require an array of operative regulations that need clarification before CCS value chains could be developed as part of the climate policy portfolio. These include regulations on pipeline standards, liability issues and emissions thresholds requirements, which will not be pursued further here (Zakkour and Haines 2007). Table 5 summarizes the political framework conditions mentioned above.

Table 5: Political framework conditions	
Basic climate policy foundations:	"Mitigating climate change requires action" "Fossil fuels will be needed in the coming decades" Criteria for climate policy instruments Confidence in CCS technologies A long term policy course
Political support for CCS:	Manipulate the cost of CCS Manipulate the cost of emitting CO_2 A long term policy course

The political aspects discussed in this section, together with the economic and technical variables as previously presented, make up important framework conditions for materializing CCS deployment within a given system, as will be pointed out below. Figure 4 comprises the main framework conditions identified in the sections above. The three categories have value as to provide analytical overview. Still, lines can be stretched across categories to point at relationships between factors that deem formal category distinctions less applicable in practice. Certainly, even additional lines could be drawn but those in place illustrate this point. Such methodological issues are discussed in section 6.2. Nevertheless, how these factors and their interplay take shape empirically in different systems and changing contextual scenarios are assessed in the following chapter. First we take a look at what constitutes changing system boundaries in this study.

Figure 4: Systemic framework conditions for CCS as a climate policy instrument



3.5 System Perimeters: Determining the Scope of the Policy Ambition

Carbon leakages and time were in the previous chapter mentioned as factors that affect how climate policy instruments are evaluated. It is therefore important to be clear on the scope of a policy instrument in order to do a precise analysis of its problem solving capacity. This section accounts for the use of system perimeters in the systemic framework model developed and subsequently applied in this study.

System borders or perimeters refer to levels and limitations in time and space. In this text they relate to technical systems, as the CO_2 value chain and electricity grid, and economic and political systems – like political entities, common markets and policy fields. The different policy levels used in the following scenarios are national, regional (like the EU ETS area) and global. Limitations in space further relate to the addressed technical systems and geography, taking into account certain stages of a life cycle, single emission sites, countries, trans-boundary regions, or the planet as a whole.[15] The application of system perimeters along the time axis take shape as the following: Immediate within the Kyoto period, short-term within the Norwegian 2020 target year, mid-term within 2050 and long-term beyond 2050. Compiled, the various system borders and factors are listed in table 6.

[15] Such broader GWP analyses assess what is called the "carbon footprint" of the services or products under scrutiny (Peters and Solli 2010).

Table 6: System boundaries

Border type	**Variations considered in this study**				
Technical system focus	Individual stages of a value chain's life cycle	Single emission site CCS chain	National	Regional trans-boundary	Global
Political and economic scope	Single emission site	National	Regional	Global	
Time perspective	*Immediate* – 2012: Within the Kyoto period*	*Short term* – 2020: Target year of Norwegian emission cuts and approaching recommended global emissions peak**	*Mid term* – 2050: Global emissions recommended cut by 25% from peak. ** Norway has been "carbon neutral" for 20 years. ***	*Long term* –beyond 2050: From this year global GHG emissions should be reduced by 80-95% **	

* UNFCCC (1998) ** Metz et al. (2007) *** Ministry of the Environment (2008)

A recently projected natural gas based iron ore production initiative in Norway illustrates how changing system border may lead to different conclusions in climate policy questions. Iron ore extracted from Kiruna, Sweden, is sent by ship from Narvik, Norway, and produced using coal power in continental Europe and beyond. Industrial actors have suggested producing ore based on natural gas power in Norway instead. This will supposedly lower GHG emissions from the iron production value chain significantly. The project would, on the other hand, lead to increased GHG emissions in Norway. Answers to how this can be solved with respect to Norwegian climate policy objectives and the EU ETS are yet unseen (Stortinget 2010). Competing perceptions of what is a climate policy entity, what are the relevant system boundaries, may lead to different conclusions in such situations – should industrial value chains or geographical and political entities of climate policy be given attention.[16]

Chapter 3 has presented a model comprising technical, economic and political framework conditions for evaluating the Norwegian CCS context. I have also presented some basic features of the CCS concept. Finally, this section has operationalized system perimeters, as they are understood in this text. Now it is time to encounter the Norwegian CCS commitment and climate policy context.

4. The Norwegian CCS Commitment: Empirical Background and Scenario Analyses

Building upon the analytical framework presented in the previous chapters, this section establishes the empirical case, namely the Norwegian CCS effort. First, the following section gives an empirical background on CCS in Norway, before section 4.2 puts the Norwegian CCS engagement in a climate political context nationally and internationally. The empirical case is thereafter operationalized in three scenarios that focus on implementation of CCS as part of the Norwegian strategy. They emphasize different sides to the Norwegian CCS effort but are not mutually exclusive. These scenarios operate within different system boundaries leading to different operationalizations of the conceptual framework conditions identified. They can therefore be understood to work along side each other as complementary aspects to the Norwegian CCS engagement.

The three scenarios illustrate the main objectives of the Norwegian CCS strategy as found by the data, but are not complete in scope. CCS

[16] Assessments of carbon leakage challenges have found that a global price for CO_2 emissions under a global cap is the most efficient and fair solution (Stern 2007). Similarly, the Official Norwegian Report no. 16 (2009a) argues how a global system perspective is the best guide to achieve "real global emission cuts."

projects could be developed elsewhere and differently than what is explored here. In a 20-30 year perspective it is challenging to foresee the relevant cases for CCS deployment in Norway (Klif 2010b). I therefore hesitate to call them empirical, as they refer to a possible future. These policy scenarios are not chosen as the most plausible given the current framework conditions, but as materializations of the stated policy priorities.[17]

Since the selected scenarios represent the current policy ambitions, one could argue that they are representative for the application of CCS as a climate policy instrument in a Norwegian context. They are not directly transferable for addressing CCS as a climate policy instrument in general, however, as they relate to the particular Norwegian CCS background, where CCS from natural gas combustion and offshore storage are particular characteristics. They could, on the other hand, be of interest for other context than the Norwegian when taking wider system boundaries into account, as we shall see. Before embarking on these scenarios, sections 4.1 and 4.2 introduce the Norwegian CCS context and climate policy commitments.

4.1 An Introduction to CCS in Norway

Although CCS has been part of the political discourse in Norway for two decades, no full-scale onshore CCS projects are built to date. Valuable experience from separating and storing CO_2 at the Sleipner and Snøhvit offshore projects have been made, but no integrated value chains yet exist. Current CCS project development in Norway include the NOK 6,5bn capture technology test center, Technology Centre Mongstad (TCM) owned and run by the Norwegian state in venture with three industrial partners holding minor shares (TCM 2011a). The TCM will be operational by the end of 2011 to try out competing technologies for post-combustion CO_2 capture for at least 5 years (Gassnova 2008).

[17] It could be worth taking into account that political support towards what CCS projects to deploy first has changed before, as we saw in the Kårstø case (DN 2010)

In addition to the TCM, the Norwegian government is expected to decide whether to contribute up to NOK 25bn in constructing a full-scale integrated CCS project for capturing and storing CO_2 from petroleum company Statoil's refinery and gas power plant at the same industrial site as the TCM (2010b).[18] The investment decision for this Mongstad full-scale project is expected in 2016, after having been postponed four years since the original plan. The Mongstad project was called Norway's "lunar landing" by the Prime minister in 2007 and has since been labeled as such - as a reference to the scale of the project and its supposedly groundbreaking technological innovations (Stoltenberg 2007). Needless to say, there is considerable political prestige invested in the project. As late as march 2011 it was characterized "a political project" by the newly appointed Minister of Energy and Petroleum (Borten Moe 2011). Already in the years leading to the investment decision for the full-scale project, the Norwegian state will contribute NOK 2,9bn in pre-construction projections (Ministry of Petroleum and Energy 2010b). The Mongstad project as a climate policy instrument will be examined in chapter 4.3.

The CLIMIT and Gassnova agencies fund public CCS R&D in Norway (Ministry of Petroleum and Energy 2004). Norwegian CCS realization targets are expressed by CLIMIT as to research and demonstrate CCS projects over the coming decade and from 2020 achieve a full-scale commercialization of the concept. CLIMIT and Gassnova combined manage an annual budget about NOK 200 million (CLIMIT 2010). 175 projects and studies have received funding from this mechanism so far (Ministry of Petroleum and Energy 2010b: 32). From previously having supported CCS from energy production exclusively, CLIMIT's mandate from 2010 also includes CCS from industrial production.

Over the last years, the political rhetoric in the national CCS discourse has seen change. The government points at projections of increased fossil fuel consumption globally to show how the TCM project *in itself* should be given more credit as a project for developing the post-combustion

[18] This sum is by many parties said to unacceptable. Lowering costs are part of the reason to postpone the decision until 2016

capture technology the world needs in order to mitigate climate change. [19] This is supposedly because the TCM is a unique test facility and because post-combustion systems can be retrofitted into existing emission sources around the world. The focus of the CCS debate in Norway now gives *technology development* as a contribution to global emission cuts more attention (Ministry of Petroleum and Energy 2010b). Critics, however, argue that this is a deliberate strategy to divert attention from repeated delays in the Mongstad full-scale project and national climate change action (Brekke and Rønneberg 2011). This capture technology R&D focus will be the basis for system scenario 2 in section 4.4.

In addition to national R&D activities, the Norwegian government also pursues its "action plan for international acceptance and implementation of CCS as a necessary climate policy instrument" (Ministry of Petroleum and Energy 2010b: 36). First, Norway seeks to anchor CCS as a credible climate policy instrument in the international climate change regime both as part of the CDM and as a stand-alone mechanism under the UNFCCC. Second, Norway seeks to contribute to widespread CCS technology diffusion in a global context. Norway therefore participates in different international forums advocating CCS R&D and deployment.[20] The international CCS effort also comes with economic incitements. As part of its EEA transfers to the EU, Norway has earmarked not less than EUR 160 million towards CCS R&D in EU member states (ibid.: 39).

Looking further ahead, an expressed vision for CCS application in Norway is the ambition of a shared CCS network around the North Sea. Here, CO_2 from emission sites across the continent would be stored under the NCS. This is a scenario that has been explored independently by various actors. Some of the required framework conditions for deploying this solution are in place, as we shall see, but significant

[19] See for instance IEA (2009; 2010c) and Metz et al. (2005), which foresee energy futures where fossil fuels and therefore CCS plays a key role in combatting climate change. In particular developing countries' growing energy is predicted met by fossil fuels. For CCS to be applied in these instances
[20] These international initiatives include among others: Carbon Sequestration Leadership Forum (CSLF), North Sea Basin Task Force (NSBT). Zero Emissions Platform (ZEP), Four Kingdom Initiative (4K), Clean Energy Ministerial (CEM) and Global CCS Institute (GCCSI), IEA Greenhouse gas R&D programme (IEAGHG)

uncertainty remains as to whether the establishment of a trans-boundary European CCS network is viable. The prospects for this CCS ambition are investigated in section 4.5. Now, the following section turns towards the climate policy targets and ambitions that the CCS track shall contribute to accomplish.

Norway has experienced a polarized national debate over natural gas fired power plants. Gas proponents wished to take benefit from natural gas resources on the Norwegian Continental Shelf (CNS) not only for export but also for use *in* Norway. Critics of Norwegian gas industrialization pointed at Norway's obligations under the UNFCCC and the Kyoto protocol, arguing that widespread gas combustion in Norway would increase national GHG emissions and that gas based electricity would dirty Norway's hydro based electricity production system (Tjernshaugen 2010). Also Norway's leadership role in the climate change regime development and particular ownership in the sustainable development narrative following the so-called "Brundtland report," complicated building new large point sources of GHG emissions (Langhelle 2001).[21]

In this context, CCS was presented as a compromise and glue for merging seemingly conflicting interests. CCS was announced as the solution to end the gas power debate as a technology to sequester GHG emissions from electricity production. It therefore seemed possible to have "emissions free" electricity from natural gas power plants (Tjernshaugen and Langhelle 2009).[22] Besides its function as the *compromise* in the national power production context, CCS also *glues* potentially diverging national interests. Norway is the world's third largest gas and fifth largest oil exporter (Lunde, Thune et al. 2008). Oil and gas sales are sources of income and an economic cornerstone that Norway would not jeopardize. Half of the country's export revenue in 2009 was provided by the fossil energy industry (SSB 2011c). Given prospects of potential production from its oil and gas fields "for many

[21] The characteristics and evolution of the sustainable development discourse is elaborated on in chapter 2.
[22] The expression "emissions free electricity production" was often used in the public debate on CCS. This was a term known by popular opinion as a characteristic of the existing hydropower production system that could help place CCS based gas production in the "lime green light" next to hydropower.

years to come," Norway sees considerable interests in continued exploitation of these resources (Ministry of Petroleum and Energy 2010a) .

On the other hand, Norway advocates the urgency of the climate change challenge and the need for deep global emission cuts. The seemingly paradoxical practice of promoting a low-carbon future while at the same time maintaining high public spending and saving thanks to extensive fossil fuels export, has been addressed as a peculiar Norwegian "Gordian knot" (Fermann 2009: 16-17). CCS may harmonize these potentially contradicting agendas. Continued fossil fuels extraction and consumption can take place if GHG releases are kept away. We see how the national circumstances for CCS engagement in Norway meet the two conditions necessary to legitimize CCS' place in the national climate policy discourse, namely a) a commitment towards combatting climate change and b) interest in continued fossil fuel consumption (Meadowcroft and Langhelle 2009a).

4.2 Norwegian Climate Policy Commitments

Norwegian climate policy commitments limit the political space of maneuvering. Internationally, the country is committed under the UNFCCC to contribute to the stabilization of GHG emissions "at a level that would prevent dangerous anthropogenic interference with the climate system" and to transition society towards sustainable development (UNFCCC 1992: 4). Under the Kyoto protocol to the same convention, Norway is committed to stabilize national GHG emissions 1% above its 1990-baseline by 2012 using domestic reductions or so-called flexible mechanisms, like the CDM (UNFCCC 1998). The 16th party conference to the UNFCCC in 2010, the COP-16, reinforced the global community's ambition towards limiting a global temperature increase at 2°C within this century (UNFCCC 2011: 3). The case for binding international GHG reduction obligations beyond 2012 is still undetermined.

On the regional level, Norway participates under the EU Emissions Trading Scheme (EU ETS). This is a GHG quota market for certain point sources, like fossil energy production, under a EU regulated cap. The cap is guided by the EU policy commitment to lowering its emissions by 20% by 2020 from its 1990 baseline and the EU-15 obligation under the Kyoto protocol. The Norwegian national quota system has since 2008 been integrated with the EU ETS, making the CO_2 quota price the same in Norway as in the other 30 participating countries (EC 2007; 2011c).

On the national level, the so-called “climate compromise” between position and opposition parties in parliament commits Norway unilaterally to reducing its GHG emissions by 30% against the 1990-baseline in 2020 and by 2030 be “carbon neutral” by taking domestic measures and using Kyoto-like flexible mechanisms (Ministry of the Environment 2008).[23] The “climate compromise” emphasizes that Norway’s international climate political credibility also depends on the country’s ability to develop internationally demanded environmental technologies in addition to decoupling economic growth from carbon emissions domestically (Ministry of Trade and Industry 2008)

Norwegian climate change policies are further embedded as *one* aspect to the Norwegian high-profile strategy on sustainable development, as one out of seven highlighted policy fields (Ministry of Finance 2008; 2010, Ministry of Trade and Industry 2008). The government says “[s]ustainable development should be a fundamental principle for all development in Norway and the world at large. To achieve sustainable development, it is important that long-term perspectives form the basis for development in society (…).” (Ministry of Finance 2009b: 41-42).[24] The indicator used in this strategy to evaluate progress on sustainable development in the climate policy area is *GHG emissions related to the national Kyoto obligation* (Ministry of Finance 2009b: 57). Sustainable development and climate change policies are understood as complementary aspects to the same ambition in other areas as well.

[23] Recently, concern about the government’s commitment towards the set targets and timetables has grown following the prime minister’s failure to answer questions on the release of a delayed climate policy white paper in 2011.
[24] My translation from Norwegian

Innovation policies fostering "environmentally friendly" technology development are also mentioned as important contributions to the sustainable development strategy. Norway's CCS technology push is presented as "a central element" of the government's innovation policy to support the sustainable development strategy (Ministry of Trade and Industry 2008).

Overall, climate policy management in Norway navigates within these international and national policy commitments and ambitions. Norwegian climate policy seeks to serve an overarching sustainable development strategy both in national and international contexts. Choosing to develop CCS as a climate policy tool in the Norwegian context is meant as a contribution to pursue the strategic sustainable development policy ambition. It also gives signals regarding the level of ambition in Norwegian climate policymaking, as we shall see in chapter 5. The rest of this chapter is dedicated towards the previously introduced scenarios. First, I address the Mongstad full-scale project.

4.3 Scenario 1: Single Site CCS at Home

In 2006 was Statoil given permission to build a combined heat and power cycle natural gas plant (CHP) at Mongstad refinery. The CHP will generate 280MW electricity and 350MW heat. All the heat and 60MW from electricity will be used at the refinery. Supposedly will 180MW of the electricity be used at the Troll A offshore petroleum platform and onshore natural gas production site Kollsnes. This leaves 40MW electricity available for the open grid, but as plans for this flow are unclear it has been left out of the following discussion. The plan includes efficiency upgrades; including heating refinery boilers with spill heat from the CHP. GHG emissions from the Mongstad refinery would decrease significantly following these efficiency gains (Ministry of Petroleum and Energy 2006). GHG emissions from the Mongstad refinery and CHP without CCS would sum up to <2 700 000 tons CO_2 per year (Statoil 2009), constituting about 5% of annual GHG emissions in Norway (SSB 2011a). A condition for the building permission was that Statoil would deploy a full-scale CCS plant partly funded by Norwegian state following a timeline decided in agreement between the government and Statoil. This CCS plant would capture about 1100 000 tons CO_2 per year of emissions from the *CHP* (which is a conservative estimate corresponding to 85% of the total emissions from the CHP) (Klif 2010b, Ministry of Petroleum and Energy 2006). Plans have been developed to include other refinery emissions to the CCS chain as well (Statoil 2009), but capture from the CHP seems to have priority from the government's side (Ministry of Petroleum and Energy 2010b).

In addition to the CO_2 source and capture capacity, the scenario makes the following assumptions about the integrated CCS system: a 60 to 100km long pipeline from Mongstad to a characterized storage site, and a characterized, safe deposit for millions of tons of CO_2 at the Johansen aquifer (Gassco 2010). The CO_2 stream is not used for EOR operations primarily because the flow from this *one* CO_2 source is insufficient (Svendsen 2005). [25]

Potential income from the Mongstad CO_2 stream for CCU purposes is limited. Use of CO_2 is currently limited to delivering 30 000 tons per year to an algae production plant (TCM 2011b). The capture plant will be the first of its kind worldwide to separate CO_2 from a natural gas post-combustion stream. The investment decision will be taken in 2016 and the plant will be operational in 2020-2022 at earliest. The project has a lifetime of 33 years (Klif 2010b: 60).

This is a system handling emissions from a single emission site, Mongstad. However, electricity generated from "CCS treated" gas will substitute onboard fossil electricity production at the Troll A platform. In national energy scope, the CCS equipped CHP has implications beyond the Mongstad site also. The political and economic implications of the

[25] Also uncertainty about the economic potential of EOR is a factor in other contexts: Different studies on the benefits from CO_2 based EOR in Norway suggest an additional 3-17% oil and gas recovered, which also would require transportation infrastructure to be built. When taking into account that commercial energy companies are far from risk prone, the case for CO_2 based EOR is weak: Oil companies would probably find developing new oil and gas fields (as in high North) a less uncertain investment.

system are primarily national, and secondarily regional and global. They are regional because of the system's attachment to the EU ETS, and global as a full-scale pioneer, demonstrating that CCS works. In terms of time, this system will become operational in a mid-term perspective. Applying the framework conditions identified in chapter 3, is this scenario feasible?

4.3.1 Technical framework conditions

We first look at the technical aspects. Here the capture technology is what seemingly is not in place, both in terms of performance and cost. The initial plan was to have the project operational in 2011-12. This has been postponed due primarily to technological issues as argued by the project developer Statoil (Ministry of Petroleum and Energy 2010b).With regards to performance, the amine-based technology option has encountered problems with potential toxic amine releases. This type of problem shift is unacceptable to the project partners and has led to delays to allow extended technology qualifications. The problem of amine releases is, however, expected to be resolved by 2016 (or an substitute technology should be available).

In terms of transportation and storage, the required infrastructure does not exist yet. Pipelines for CO_2 transportation are not in place. Nor are injection installations in place. New seismic data has been gathered for the Johansen formation in 2010, however, and the site will be characterized in time for project launch. As for operative regulations, "how to do transportation and storage" is not decided yet, but a directive based on the EU storage directive is in the pipeline. These operative regulations will be finished in time for the project launch. In fact, all regulative and "physical" aspects related to transportation and storage for building a CCS value chain in Norway follow the timetable of the Mongstad full-scale project investment decision. [26]When this decision is postponed, so are regulations on "how to do" CCS in Norway.

[26] Courtesy of an interviewee

4.3.2 Economic framework conditions

Considering the economic conditions, the latest cost figures are too high, some parties say. Since the initiation of the project the overall cost estimates have increased by 500% now counting NOK 20-25bn for this CCS plant alone. Pre-construction preparations add up to NOK 2,9bn.[27] Costs should be decreased by 2016 if the project is to be built (Borten Moe 2011, Solvik-Olsen 2011).. In addition to being the first of its kind, the main factor making this project more costly than other full-scale projects is the fact that retrofitting a capture plant into an existing complex industrial facility is harder than building the whole infrastructure from scratch. Objectively speaking, if one wanted just to construct a full-scale CCS value chain, there are less hard and less expensive ways of doing it than at Mongstad.

The Mongstad project has one major benefit that renders the price of other climate policy tools almost uninteresting: “This is a political project,” rephrasing the OED minister. Particular political support for this project guarantees its fulfillment and if this support comes to an end, it is likely that the project will too. In order to decrease the price of the project, the investment decision is postponed to allow R&D activities and pre-projecting.

Given this particular situation, a CO_2 price instrument is worthless. Currently fluctuating around EUR 20 per ton, the price of CO_2 in the EU ETS is far below what would otherwise spark this type of project. Current estimates of the Mongstad CHP CCS project indicates CO_2-avoided price around NOK 1300-1800 per ton (Klif 2010b, Statoil 2009). In long term projections of the quota price under the EU ETS, the CO_2 price does exceed EUR 48 per ton (NOK 400 approximately) (ZEP 2011). The market for CO_2 quotas is therefore not a predictable means to facilitate the required long-term investment climate for CCS investments.

[27] However, the revised national budget for 2011 indicates a NOK 0,94bn decrease in transfers to the Mongstad project, and storage site preparations in particular, this year. According to the OED this is a postponement following ”adjustments in the timetable”, while ENGO Bellona sees it as another sign of downplaying government`s stakes in the project (Tveit 2011)

4.3.3 Political framework conditions

Without considerable political support expressed in monetary transfers to the Mongstad project, it would be an economic dead end. Political support being a major advantage of the project, the existence of viable industry partners is another. Arguably, given the modest size of the Norwegian economy, few – if any –Norwegian companies are better suited than Statoil with its history of large-scale industry projects and CO_2 storage. Government ensures funding while Statoil is responsible for executing the project.

As demonstrated in the previous section, climate political conditions in terms of national commitment and international obligations are in place. The role of political support for this project is its strength and weakness. Political dedication can push it through even when the economic or technical conditions are not ideal. However, this is also its Achilles heel: The project comes to an end if that massive political support fails – for example following a change in government after national elections in 2013 or a complete breakdown of the global climate regime.

In many aspects, materialization of CCS in Norway follows the Mongstad project so closely that a national CCS application policy and the Mongstad project may at times be hard to distinguish as different policy levels. Interestingly, competing industrial actors have proposed to build gas power plants with CCS elsewhere in Norway, using pre-combustion technology, which is faster and less expensive. These have not received any economic support by the state (Solvik-Olsen 2011). Nevertheless, the present cost estimate is unacceptable compared to the other policy alternatives available, which increasingly includes building CCS somewhere else in Norway. State owned agency Gassnova has been given a mandate to study the potential for other CCS projects in Norway in addition to Mongstad (Ministry of Petroleum and Energy 2010b). What follows that assessment will be interesting to see and is beyond the limits of this text.

After having assessed the various framework conditions to discuss the features of the scenario, the perhaps most interesting question remains:

Using the established typology from chapter 2, how and to what extent does CCS deployment within this scenario qualify as a climate policy instrument?

4.3.4 The Mongstad full-scale project as a climate policy instrument: An effective contribution?

First, it is clear that the CCS project at Mongstad would not be initiated if it were not for concerns over climate change. The project will reduce emissions from the CHP substantially, capturing 85-95% of emissions. Generally, in an LCA perspective such a plant will *avoid* 65-75% of emissions, as we have seen (Singh 2011). This is a climate policy tool primarily when compared to *not* building a CCS plant at Mongstad, which requires a single-site perspective. Secondarily, for the Troll A platform in particular, a cleaner electricity source will phase out a carbon intensive solution. In a wider perspective, however, the energy structures will remain the same. The system facilitates continued consumption of natural gas, a fossil energy source that from the NCS may last 50-100 years.[28]

Looking at the time perspective of the expected emission cuts, no reductions will take place in the *immediate* term. Also in the *short* perspective, before 2020, no emission reductions can be made. It is in a mid to long time perspective that this project can perform as a climate policy tool, that is 2020-2050. This being said, the project perspective cannot be too long-term either when taking the finite fuel stock and lifetime of the project into account.

The cost-efficiency of the emission cuts is not favorable in the short run. Technology development and infrastructure deployment is costly at this pioneering stage.[29] Per ton CO_2 avoided, other GHG mitigating measures are more cost-efficient (not at the Mongstad site, but in a national or international context). This system does best if it could substitute more

[28] This time estimate may not be very accurate. In 2002 it was projected that Norway had natural gas sources for 100 years of production at that year`s extraction rate. In 2010 the production rate was doubled (Ministry of Foreign Affairs 2002, SSB 2011b). What is less uncertain, however, is that there is enough gas in Norway for a few decades` production while global natural gas supply may last up to 250 years.
[29] Investing in equipment is expensive also because manufacturers cannot sell their new products with warranties, which raises investment risks further.

polluting energy sources, like those at Troll A. At the Mongstad site perspective, CCS is merely an advanced end of pipe-solution. It is therefore in a mid-term, transitional perspective where fossil fuels still are high in demand, but where restrictions on GHG emissions are enforced, that this CCS system contributes more in a climate policy perspective. For reasons like conflicting future scenarios and policy paths, when the *transitional* character of this period starts and ends is not entirely clear. Sunk costs related to this project are intensive and it is therefore likely that actors will wish to exploit them to their fullest extent for as many years to come as possible. Having addressed the Mongstad project in this section, the following section at a scenario where technology development is in the front seat.

4.4 Scenario 2: CCS Technology Development for Global Utilization

This scenario focuses on CCS technology development in a global setting. How can the TCM system work as a climate policy instrument and under what framework conditions? It emphasizes the role of technology development as a facilitator for widespread CCS deployment: ”An (…) important objective for the Norwegian technology and competency development is that it comes to use also outside Norway. It is when this happens one will achieve significant GHG reductions following the Norwegian [CCS] commitment” (Ministry of Petroleum and Energy 2010b: 9).[30] How the TCM is functions as an operationalization of that commitment is addressed in the following.

4.4.1 Technical framework conditions

To begin with the technical aspects, this system does not assume an integrated CCS chain. It concentrates around post-combustion capture technology. The TCM is built to test two technology types at the time under varied exhaust conditions simulating industrial off-streams, coal

[30] My translation from Norwegian

and natural gas power plants. Currently Aker Clean Carbon "rents" a technology test slot for its amine-based technology, as does Alstom with its ammoniac-based alternative (TCM 2010). The two technology developers lease from the owning venture, TCM DA, on five-year contracts. The ambition is that the TCM will contribute to lowering the price of post-combustion technologies to facilitate a commercial breakthrough not only in Norway, but where it is needed the most: In coal intensive economies with increasing energy demand. Lessons learned from this test phase will also be used to pre-qualify technologies for the Mongstad full-scale project.

4.4.2 Economic framework conditions

Looking at economic framework conditions for this system, the cost of other climate policy instruments is, as in the previous scenario, less important due to the project's political foundation – as opposed to a project sparked under a flat market regime. This project does not lead to quantifiable emission reductions but is primarily an innovation promoting measure. That makes public support mechanisms for CCS R&D more important. The Norwegian state holds a majority share of the TCM DA, funded over the state budget. The project is estimated to cost taxpayers NOK 6,5bn (St. Meld. 2010-2011). In addition to direct transfers, Gassnova has a mandate to support CCS research and pilot projects with an annual budget about NOK 200 million together with the CLIMIT research program. Now also industrial CCS pilots are entitled to apply for public R&D-funds (Ministry of Petroleum and Energy 2010b).[31]

4.4.3 Political framework conditions

This global effort towards CCS deployment depends on several international *political* framework conditions. First of all, it requires an international climate regime where CO_2 emissions are restricted and where CCS is regarded a viable GHG mitigation measure. The current regime is politically set to stabilize GHG emissions within "a safe level"

[31] This is an opportunity the newly initiated cement factory NorCem's CCS project hope to benefit from.

and bound under the Kyoto protocol and its flexible mechanisms. CO_2 storage at Sleipner and Snøhvit are reported in Norwegian national inventories as sequestered emissions (Klif 2010c). However, CCS was not regarded a climate policy instrument under the CDM until COP-16 in Cancun, Mexico, in 2010 (Pileberg 2011).[32] Norway has been in the forefront advocating CCS' inclusion into the mechanism, particularly after the concept gained momentum following the IPCC special report on the technology in 2005 (Metz et al. 2005). With CCS accepted as a viable GHG abatement instrument by the only, somewhat functioning, global marketplace for GHGs, an important step was taken to facilitate and legitimize global CCS diffusion (de Coninck 2008, Scorse 2010: 91-92). In the post-Kyoto period, what CDM-like mechanisms and global climate targets to be decided are yet to see.[33] Since also the TCM project is funded and dependent on political support, it is not vulnerable towards market changes but towards change in political course – which may decide its fate after existing contract obligations terminate after 2016.

Having created international acceptance for the CCS *concept*, operational regulations on trans-border activities need to be decided. How CCS is to be conducted under the CDM is to be discussed in relation to the COP-17 in Durban later this year.[34] As we shall see in the following section, also other international treaties need clarification before international transportation and storage of CO_2 is ready for deployment.

The institutional and political feasibility of achieving widespread CCS technology diffusion following the TCM project is demanding when taking the above requirements for international success into account. On the national level, the main challenge is to keep technology developers demanding using the TCM. This is a challenge that is also linked to international trends and outsights. An international commercialized CCS value chain is explored in the following section. Before turning towards

[32] This was not an easy negotiation among parties to the Kyoto protocol. Norway, Canada and OPEC countries advocated CCS in the CDM, while Brazil and Venezuela lead the opposition. See for example van Coninck (2007; 2009)
[33] A further discussion on the future of the climate regime is beyond the scope of this study.
[34] IPCC's suggested guidelines for CO_2 storage and reporting from 2006 are not found applicable to the parties.

the final scenario to be examined, it is worth looking at the value of this system as a climate policy instrument.

4.4.4 The Mongstad Technology Centre as a climate policy instrument: An effective contribution?

Using the typology from chapter 2 it is hard to characterize the TCM's immediate value as a climate policy instrument. We are talking about a project for technology developing that does not lead to lowered CO_2 emissions on its own. Instead, it is a project to facilitate commercialization of post-combustion CO_2 captures technology in an international setting. The time perspective is at least mid-term: That is beyond 2012 and at earliest towards having market ready solutions after 2020 along with Norwegian CCS commercialization targets. The fate of the TCM after the first test period post-2017 is still undecided, however.

What could be mentioned in this context, moreover, is the possibility of Norway buying CDM-like emission quotas from building CCS plants in developing countries based on cost-efficient capture technology developed at the TCM if the project deems successful. The TCM could in time relief Norwegian GHG emission cuts and national inventories by taking CCS-based cuts abroad under a future CDM-like mechanism. This type of global application of CCS would in turn prepare the ground for continued use of fossil fuels in a "carbon restraint future," allowing continued Norwegian oil and gas exports to be perceived as legitimate.

Criticism of the TCM project suggests that retrofitable post-combustion technology will not be demanded internationally because it is too expensive. For new built plants will pre-combustion solutions be the least costly option if choosing CCS at all, a study argues (Greaker 2011). The risk taken by the Norwegian state in its international CCS engagement should be underlined: If post-combustion capture in particular and CCS in general is not successful as a demanded technology and climate policy tool internationally, history may find that allocating limited time, resources and attention towards this technological "dead end" was wasteful use of the (final?) chance to avoid dangerous anthropogenic climate change.[35]

This scenario seems to describe a type of climate policy related activity best picked up by the technology specific criteria in the typology developed in chapter 2. It may very well be a contribution towards international technology development, given that post-combustion CCS will be in demand as a GHG abatement instrument beyond Norway. Certainly, it is innovation policy and it certainly is a contribution towards demonstrating that CO_2 capture works. This may further mature the market for CCS solutions, which in turn serve at least two interests, namely reduction of GHG emissions and continued fossil fuel consumption. How this global technology development aspect to the Norwegian CCS effort can bee seen more broadly in a climate policy context will be discussed further in chapter 5. The next section looks at a fully integrated, commercial European CCS based CO_2-value chain.

4.5 Scenario 3: Commercializing CCS – Towards a European Value Chain

The idea of an integrated CO_2 value chain based on storage sites in the North Sea has been discussed jointly by the Dutch, German, Norwegian and British governments (ElementEnergy 2010), the European Union (CO2Europipe 2011), ENGOs (Stangeland 2007) and others (Granbo 2009). These contributions represent the vision of an integrated CCS network in Europe with joint storage under the NCS. In this scenario, several European point sources of GHG emissions have CO_2 capture plants installed, like coal power stations in Germany and Dutch refineries. The CO_2 is sent by pipeline to a hub in the Netherlands and further via pipeline or ship to a permanent storage site in the Norwegian sector of the North Sea. In Norway too, CCS-fitted CHPs produce electricity for the grid and contribute CO_2 to the same storage sites. In total, the CO_2 stream from all emission sources is large and stabile enough to allow

[35] Courtesy of an interviewee

EOR from for example Norwegian gas fields Statfjord and Ekkofisk (ElementEnergy 2010). In order to contribute to the recommended global emissions peak, and before being outcompeted by alternative GHG abatement instruments, this system should be operational between 2020 and 2030 (ibid.).[36] As a so-called commercialized CCS system, its realization is in principle left to industry choosing it as the most cost-effective means of emission mitigation. Although hypothetical, the scenario represents an outline of what CCS deployment to the fullest extent may look like in a Norwegian and European setting.

4.5.1 Technical framework conditions

Looking at facilitating the technical framework conditions for this system: What should be in place and what is the current situation? This system would operate under the EU ETS, meaning that its cost efficiency is relative to the price of other GHG abatement options. Capture technology is currently too costly for reasons explained in section 3.1. Investment costs for transportation infrastructure are also considerable. None of the envisioned infrastructure or capture plants exist today and need to be built for the scenario to materialize. Suitable storage sites are probably less difficult to prepare. The Johansen and Utsira formations are nearly characterized and said to be able to store CO_2 amounts equivalent to decades of emissions from a large European CO_2 chain (Gassnova 2009). Operative regulations on how to do this are in the pipeline. Member states are given until June 2011 to implement their harmonized version of the EU Storage Directive (EU 2009).

In order to contribute to commercializing capture technologies, the EU is subsidizing at 6-15 pilot projects by 2020 funded by the sales of 300 million ETS quotas and EUR 1bn from the European Energy Programme for Recovery. Since much of this funding is based on future sale of ETS quotas, with a price subject to change, the real impact of the contribution remains to be seen (but may end up around EUR 4,5bn) (EC 2011a; b). The role of CCS in EU and its impact on the Norwegian CCS

[36] Courtesy of an interviewee

engagement and international deployment reaches past the aim of this study.

Beyond the EU scope, international conventions OSPAR[37] and London protocol[38] regulate cross boundary pollution in the North-East Atlantic Ocean and world oceans respectively. Both agreements' texts have been changed in order to allow cross border transportation of CO_2 and permanent sub-sea CO_2 storage. Norway was the initiator of the process in both instances.[39] Currently, the two agreements await 1-2 more ratifications each to enter into force (Dixon 2009). The necessary implementation into national laws is expected to take place soon and leave the way open for cross-border CCS projects like the ones discussed here.

4.5.2 Economic framework conditions

Turning towards other economic framework conditions, the EU ETS has already been mentioned. Under this regime, the quota price needs to increase significantly in order to make CCS cost efficient, even if the technology should breach important cost reducing barriers. At an early technology stage will a ton CO_2 avoided cost EUR 60-90 from a CCS-fitted coal power plant, while the quota price is not expected to exceed EUR 48, as previously discussed (ZEP 2011). Given the ETS' currently low quota price, uneven track record and unpredictable future, it is difficult to create and maintain a foreseeable climate for CCS investments of the scale required for this scenario to take shape. The economic framework conditions are not in place. CCS technology is just too expensive. For decision makers in industry under the EU ETS cap, CCS investments are currently subject to unacceptable risks and uncertainties.

What might interest industrial partners, however, are prospects of revenue from EOR operations. Oil companies are likely to take interest in developing this practice given that a credible CO_2 stream and

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[37] The Convention for the Protection of the marine Environment of the North-East Atlantic

[38] The Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

[39] Courtesy of an interviewee

infrastructure are already in place. EOR with oil companies onboard are probably necessary requirements for this scenario to materialize.[40] Who would pay what to fulfill this activity is unclear, of course.

4.5.3 Political framework conditions

Taking also political framework conditions into account, the level of GHG cuts and ambition in international climate policy will decide the EU ETS quota market cap and CO_2 price. The more ambitious climate targets, the higher quota price. Economic conditions for implementing the CCS network are to a large extent determined by political ambitions, like in the first scenario, but here are the price of CO_2 and competing GHG reducing measures given more attention over direct public "hands-on" engagement in the individual project CCS plant. In both instances are policy-makers holding the key for emission cuts and CCS deployment.

As we have seen, political efforts have already been made to modify the international law necessary to allow cross border CO_2 transportation and storage. Still, more political and regulatory issues need attention. How international CCS activities should be counted under the EU ETS and UNFCCC are not yet determined, but these regulatory issues can be resolved as the scenario becomes more tangible (Ducroux and Bewers 2005). Contrary to the Norwegian context, popular opposition towards CCS is substantial in many countries – both due to perceived risk of leakage and criticism against the concept as a counterproductive means of mitigating climate change (Meadowcroft and Langhelle 2009b). Also these domestic aspects should be accounted for in a European political context. Multilateral working groups work to develop enhanced political momentum for this scenario to develop (Ministry of Petroleum and Energy 2011, NSBTF 2011)

For Norway in particular, this system might be of special interest in a climate policy perspective. Given beneficial regulations under the EU ETS and UNFCCC, as a country owning excess storage capacity,

[40] Courtesy of an interviewee

Norway might be able to sell CO_2 storage capacity and liability commitments to other CO_2 producing countries along the CCS chain (Granbo 2009). This could potentially balance Norway's national GHG records (or inventory) so that fewer emission cuts would be needed onshore Norway.

4.5.4 The European value chain as a policy instrument: An effective contribution?

As a climate policy instrument, this scenario is more complex than the ones previously assessed. It combines CO_2 streams from existing emission sources in several countries. In that sense its contribution to sequester large amounts of CO_2 from many point sources might be an important contribution to reduce European GHG emissions, at the same time as it allows the existing energy economy to prevail. That said, time and cost aspects are challenging to determine. Certainly, this system could not be established over night. It can at earliest be established in 15-20 years and most probably in a 30-40 year perspective, which is late if it is to contribute to existing climate policy goals. That indicates a mid-term to long time perspective. It might, on the other hand, contribute to postpone more profound structural energy system changes, which would be more costly to take in the short run. In a European context, this scenario would lower emissions on a single emission site basis among the emission sites equipped with capture facilities attached to the CO_2 value chain. It could in a best case also lead to lowered GHG emissions from the large fossil fuel based energy sector in Europe:

Exemplified with the Norwegian gas power plants as part of the European electricity production system, an important question that applies also to other industrial activities being part of the CCS network arises: Given an increasingly integrated European electricity market, will the new electricity generated from the CCS equipped gas power plants phase out more polluting fossil fuel fed power production elsewhere in Europe? If the answer to this question is "yes", chances are that the network has a GHG mitigating effect in this broad system perspective. If the answer is that the electricity comes *in addition* to the existing electricity supply, the GHG mitigating effect of this scenario is more questionable. These considerations should be taken into account before labeling this CCS scenario as an obvious climate policy measure.

Further, given that EOR activities based on captured CO_2 are conducted to add up the economic equation of the CCS value chain, how is the additionally recovered oil and gas accounted for in a climate policy perspective? Is the GHG mitigating effectiveness of the CCS network reduced if these hydrocarbons are combusted without CO_2 capture? Or could EOR in existing production fields make new oil and gas production in new fields unnecessary? As repeatedly discussed, a climate policy instruments' problem solving capacity often depends on where its system boundaries are drawn.

Along the established typology, this scenario offers an end of pipe solution for the individual emission sites. At the same time, this CCS network proposes a broad solution towards mitigating GHG emissions from a whole energy production system that also ensures the continuation of the existing fossil fuel based energy economy – which is beneficial if no alternative energy carriers are available in required quantities. Especially if given prospects of increasing demand for electricity and industrial products, this system may contribute to decrease the CO_2 component from energy production and consumption in Europe and thereby function as a transitional tool towards a "low carbon economy." What is clear, at least, is that the CCS network is not a *sustainable* solution. The question is instead whether it provides a necessary fix to a problem that otherwise cannot be solved, or if it rather contributes to prolonging a fossil energy era "unnecessarily" by furthering carbon lock-in.

Turning away from what is starting to look like an early debate over the CCS concept as a climate policy instrument general, chapter 5 gathers findings from the three scenarios above and pulls together the treads in an overarching discussion on the use of CCS as a climate policy instrument in a Norwegian context – both more narrowly or widely understood.

5. CCS in a Climate Policy Perspective in a Norwegian Context: Final Analysis

The three scenarios presented in chapter 4 outlined different aspects to the Norwegian CCS effort spanning from gas power cleansing in a domestic context, to technology development and demonstration in a global setting, and finally to the ambition of an integrated regional CCS value chain where Norway takes part. This chapter offers a wider discussion on the Norwegian CCS effort, taking findings from chapter 4 into account. How are the three CCS scenarios best understood in terms of feasibility and performance as climate policy instruments?

5.1 Overall Assessment: CCS as a Climate Policy Instrument Concept in Norway

Given that the scenarios above develop, how can CCS function as a climate policy instrument in a Norwegian context? First, as seen from a *single site perspective*, a CCS equipped CHP results in substantially lowered GHG releases than a CHP without CCS, also in a life cycle perspective (65-75% lower GWP). CCS leads to fewer emissions than a BAU scenario and is conducted primarily to mitigate GHG releases, like we saw at Mongstad full-scale example. CCS can therefore be understood as a climate policy instrument in this context. Its performance as such is debatable, however. This is an *end of pipe solution* in a single site perspective. It provides a fix to the GHG problem, but does not lead to lowered resource throughput, and rather to the opposite in terms of energy consumption. It may therefore not be seen as other than an incremental improvement of an existing technological track – although its implications may be important. Its functional orientation has potential in terms of CCU or EOR, but the cases for these applications are rather weak at the moment.

Seen as part of a broader technical system, on the other hand, CCS may also have *transitional* qualities. This is applicable if considering electricity flows from a CCS equipped power plant where the electricity generated *phases out* more polluting alternatives, as would be the case in the Mongstad CHP to Troll A. Also a widespread European CCS network could be labeled as such if CCS-based electricity takes over for non-CCS fossil fuel in a considerable scale. The main question is whether CCS based electricity *phases out* or comes *additional* to more polluting alternatives – both in terms of electricity and products manufactured using CCS-based power. In a wide system perspective, this also goes for the EOR potential of the trans-boundary network scenario, where hydrocarbons recovered from CO_2 based EOR would have to be accounted for in a climate policy context (would CO_2 from their combustion also be sequestered or not?): Are the "loops" closed?

Although performing better than a BAU and having *transitional* features at best, using CCS as a climate policy instrument is hardly *sustainable*. The concept is based on a finite energy source and has few environmental or resource related benefits other than controlling GHG emissions to the atmosphere. It provides a technological *fix* to one of the drivers of unsustainable development, namely climate change, but contributes in the same breath to continued fossil fuel consumption, underpinning the existing energy economy. The decisive question is to whether a fossil fuel based energy system is the inevitable energy future or if realizing widespread CCS deployment leads to prolonging the fossil era unnecessarily – if resources spent on CCS amplifies unnecessary carbon lock-in. As we have seen, agenda setting energy projections find widespread CCS deployment necessary to combat climate change drivers and meet future energy demand. That said, projections are merely projections. To what extent is the energy future what we make of it? The more confidence (or even interest) one has in the necessity of fossil fuels as *the* major energy source also in the coming decades, the more sudden seem the transitional aspects of CCS as a climate policy tool. As we have seen, Norway has significant interests in continued fossil fuel consumption. Table 7 summarizes the general findings pointed at in this section. Greyed out boxes reflect characteristics of the Norwegian CCS commitment as an aggregation of the three scenarios assessed.

Criteria for evaluation	**Table 7: CCS in Norway categorized as a climate policy instrument**			
	Non-climate policy	**End of pipe solutions**	**Transition solutions**	**Sustainable development**
Empirical examples	Replacements for CFCs in cooling systems CO_2-based EOR	Exhaust gas treatment from industrial sites: NO_x and SO_x cleansing of smoke stacks	Packaging recycling. Replacing coal with natural gas as energy carrier	Long lasting renewable energy systems "Natural" bio-energy for heating
Strategy of inspiration	*No regret actions*	*End of pipe solutions*	*Cleaner production*	*Industrial Ecology*
Main goal served	Other than GHG abatement	GHG mitigation	GHG mitigation	GHG mitigation
Potential other goals served	Any, including GHG mitigation as a "no regret measure"	Cost-efficiency, other environmental impacts	Other environmental impacts, cost efficiency, lowered resource consumption	Other environmental impacts, cost efficiency, sustainable resource throughput
Cost-efficiency and time perspective on problem solving capacity	Varies	*Short term*: High as few structural changes are needed. Early GHG cuts over expensive systemic changes prioritized. *Long term*: Low because more profound system changes may be required in the future.	*Short term*: Varies, some structural changes needed. Attention given transitional solutions towards a greener society. *Long term*: Potentially high as some structural changes are taken	*Short term:* Potentially low, because expensive structural changes are needed. Long lasting change over low hanging fruits emphasized. *Long term*: Potentially high because beneficial structural changes take place
System focus	Varies	Single emission source or life cycle stage perspective	Improved sector or life cycle perspective	Complex system perspective towards both human and natural systems
Process and function orientation	Varies	*Limited* – processes and resource consumption remain the same to maintain low investment costs	*Some* – recycling and smart use of resources take place requiring some system change	*High* degree of functional orientation
Related technology change and contribution towards international technology development	Varies	*Incremental improvements* – limited technology development contribution from solutions based on known practice	*Radical innovations* – Significant technological development contribution following process oriented innovation	*Technology system change* - Potentially very valuable technological contribution if international trends shift towards sustainable development
Institutional and political feasibility	Feasible and common, especially since meeting other interests facilitates action	Feasible – The approach towards climate policy measures is often framed as a question of cost-efficiency in a short-term perspective. Only basic commitment towards climate policy required.	More demanding and more challenging, but still feasible because relatively low hanging fruits from cost efficiency gains following process improvement take place	Demanding to gain acceptance for investing in structural changes and shift towards a functional orientation – requires broad societal change beyond investments in technical innovation.

5.2 Overall Assessment of the Framework Conditions for CCS as a Climate Policy Instrument in a Norwegian Context

Deployment of CCS in Norway requires extensive public support in terms of R&D, direct monetary transfers, foreseeable incentive structures and encouragement. In addition to taking measures to increase the cost of emitting CO_2, making CCS competitive in a market like the EU ETS conditions specified subsidies. This prompts public innovation policies to support CCS development in particular, as Gassnova and CLIMIT does in Norway. An implication of this approach is that government picks winner solutions to GHG emission mitigation at an early stage. This is of course a deliberate policy. As politics is always a struggle over limited resources, an interesting question remains as to what extent specific support to CCS might come at the expense of other "climate technology" innovations?[41] [42]

Not only is CCS expensive, it is also slow to deploy in a Norwegian context. As a climate policy tool CCS in 2011 can be nothing but subject to innovation policies, demonstration activities and building acceptance for future widespread application. Capture technologies face cost barriers, few storage sites are characterized and transportation infrastructure is not in place (but will be in place if full-scale capture at Mongstad is decided). Transport and offshore storage is in Norway perceived to be well understood and uncontroversial as long as the CO_2 is injected into a characterized deposit and monitored after injection.

In a Norwegian context particularly, it is post-combustion capture technologies that not yet are ready. Scenarios assessed in this study find that the first Mongstad full-scale plant may be operational in 2020-2025 at earliest. A European full-scale network can be operative in a 20-30

[41] In the EU it is not allowed to subsidize CCS at the expense of other climate policy measures. How this can be discovered and enforced is yet to be seen.

[42] As possible consequence is discussed in Fermann (Fermann 2009: 19), suggesting that otherwise Norwegian renewable energy research and investments take place outside Norway as a strategy of "diversification through internationalization" when incentives for conducting such activities are significantly weaker in Norway than in other countries.

year perspective. This is of course too late to impact Norwegian Kyoto obligations and also too late to contribute to the national 2020 target. It is post-2020 that CCS can first perform as a climate policy instrument. Climate political and economic framework conditions and incentive structures are uncertain in that time perspective. This is where the TCM initiative plays a particular role. If successfully contributing to CCS technology diffusion and acceptance, the TCM may influence the international and national agendas so that climate policy makers will take CCS into account also in the coming decades.

5.3 CCS: An Effective Climate Policy Instrument in Norway?

As a climate policy instrument, the previous sections established CCS as an end of pipe solution or a transitional measure under the right circumstances. I have also found that materializing full-scale CCS in Norway is expensive and faces sub-optimal framework conditions. In the "worst case", CCS as a climate policy instrument could therefore end up as an *expensive technological slow fix* to a prevailing problem. For that reason, before investing technical, economic, and political resources on rolling out its full potential one should consider what questions and uncertainties one gives answers to by forcefully commercializing CCS. How effective is CCS as a climate policy instrument in a Norwegian context?

We recall how Norwegian climate policy shall fulfill both quantifiable emission targets, the Kyoto obligations and the national "climate compromise," and also underpin the sustainable development strategy. If CCS as a climate policy instrument fails to meet both emission targets and to contribute to sustainable development, how well suited is it really as a climate policy instrument? Considering policy instruments like CCS, as *means* to achieve long-term climate policy and sustainability ambitions, comparing their implications to a BAU scenario is an incomplete basis for decision-making, as discussed in chapter 2. A policy is not sustainable just because it is better than BAU.

When looking at Norwegian climate and sustainability indicators, it may therefore be fair to suggest that it is imprecise to operationalize climate policy contributions towards sustainable development in terms of national GHG emissions relative to the national Kyoto target alone, as done in Norwegian policy making. The question addressed in section 5.1 remains as relevant as ever; is CCS a meaningful contribution towards sustainable development as a *transitional* instrument or not? Arguably, the current Norwegian climate policy indicator does not pick up this aspect, which is a crucial consideration to make when undertaking as significant investments as CCS development and deployment labeled as climate policy in support of the sustainable development strategy. Failing to do so allows a lowered ambition level in climate political decision-making.

The suggestions above implicate that CCS, although having GHG reducing potential as a climate policy instrument, leads to sub-optimal *means-goal efficiency* in Norwegian climate policy. The climate policy *intention* is not sufficiently met by CCS as climate policy *behavior.* If this is harsh, a less normative observation can be made using Young's (2010) dichotomy to suggest that CCS as Norwegian climate policy belongs in the "GHG control track", and not in the "de-carbonization of society" track.

Politics is the art of what is possible. Despite delays and controversies, the fact that CCS goes forward in Norway cannot be accredited to the concept's potential as a climate policy instrument alone. It is therefore relevant to look for other interests aligned to make support for CCS sufficiently broad. As we have seen, Fermann (2010) and Tjernshaugen and Langhelle (2009) have previously addressed CCS in Norway as a strategy to harmonize Norwegian fossil fuel interests and climate policy engagement. Even if the Norwegian fossil energy industry complex has not been under particular scrutiny with regards to potentially vested interests in this text, it is evident that CCS application in Norway builds on the two basic foundations for CCS in a climate policy perspective, namely: a) continued fossil fuel consumption with b) restrictions on GHG emissions (Meadowcroft and Langhelle 2009a). [43]

6. Summary and Conclusion

This chapter presents a summary of the text and offers a few concluding remarks on the overall study at hand. This is done in sections 6.1 and 6.3, respectively. In section 6.2 I raise awareness on the methodological choices taken in this study that may be of concern. First, I start off by restating the study's empirical point of departure, research question and objectives. I thereafter recapitulate its structure and findings.

6.1 Summary

By isolating and storing CO_2 from fossil fuel combustion, the CCS concept promises fossil fuels consumption without emitting of GHGs in large quantities to the atmosphere. Proponents of the concept argue that this is good news for climate change, when taking projections of growing global energy demand and continued reliance on fossil fuel into account. Meanwhile, the IPCC recommends that global GHG emissions should peak by 2025 and be reduced by 25% by 2050 in order to limit the chances of dangerous climate change, caused by anthropogenic GHG emissions. This background constitutes the climate political rationale for widespread CCS application.

In Norway, CCS is described to harmonize potential conflicting interests when confronting the country's fossil fuels dominated exports economy

[43] Being off-topic of the present research question, though still an interesting but unspectacular observation could be made if suggesting that the principles and objectives of climate policy in Norway, with its focus on international GHG emission markets and CCS, seem to facilitate the fossil fuel based energy policy. This could be an interesting field for future study.

with the country's GHG reduction commitments under international and national climate policies. The government points at the IEA energy projections to emphasize the importance of CCS as a GHG reducing measure in an international setting. Building gas power plants with CCS has been framed as the solution to the polarized "gas power debate" in the domestic setting.

CCS is promoted as key aspect of the government's climate policy. Norwegian climate policy obligation binds Norway under the Kyoto protocol. The unilateral "climate compromise" also commits Norway to reduce its GHG emissions by 30% against the 1990-baseline in 2020 and be "carbon neutral" in 2030. Norwegian climate change policies are part of the national sustainable development strategy. Sustainable development and climate change policies are understood as complementary aspects to the same ambition.

This study has engaged the concept of CCS as a climate change mitigation measure by asking *under what framework conditions CCS may function as a climate policy instrument in a Norwegian context*. The text has addressed three main objectives. First, the term "climate policy instrument" was given an operational definition. Second, I have identified and described relevant framework conditions for using CCS as a climate policy instrument in a Norwegian context. Third, after having built the analytical framework above, the final analysis has discussed the Norwegian CCS initiative to answer the main question at hand, namely how the Norwegian CCS engagement may function as a climate policy instrument.

I have assumed an institutional approach to political economy where the relevant framework conditions for the market economy reflect a policy course that sanctions certain economic activities intentionally. Linking this with the understanding that materializing CCS in Norway is a case of innovation and diffusion of new technology, I point at political, economic and technological framework conditions as explanatory factors to study the Norwegian CCS effort in a climate policy perspective. The role of shifting system boundaries has ben given attention in this regard.

Also taking different levels of climate policy action, cross-border energy flows and CO_2 transportation infrastructure into account are relevant implications of Norwegian climate policy that go beyond the country`s geographical scope - in both technically and politically.

Chapter 2 presented a definition of what is a “climate policy instrument”. I identified relevant criteria for evaluating climate policy instruments. Particular attention was given to the role of technological innovations as solutions to climate change mitigation. I defined climate policy instruments as primarily motivated by GHG emissions reduction. I suggested a typology distinguishing different qualitative approaches to climate policy instruments spanning from *end of pipe solutions* to *sustainable development*. These conceptual and operational clarifications provided the basis for the subsequent evaluation of the Norwegian CCS effort.

Chapter 3 presented the analytical model to evaluate the empirical case as a climate policy instrument, as defined in chapter 2. The model addressed political, economic and technological framework conditions likely to determine the extent to which CCS could be considered as such. Political framework conditions focused on political will to limit drivers of GHG emissions from human activities, towards CCS as a viable emissions reduction option, and willingness to manipulate structural economic conditions to facilitate commercializing the concept. Economic framework conditions included factors making CCS more or less cost-efficient compared to other GHG mitigation options. The price of CO_2 emissions, mechanisms for public support and creating a foreseeable environment for investment were emphasized. Economic framework conditions also included capital costs of infrastructure and technology deployment as a function of technological learning. The assessed technical framework conditions looked into the technical feasibility of delivering CCS solutions at acceptable performance and cost. Also the main stages of an integrated CCS project were presented in this chapter. Finally, chapter 3 explained the concept of system boundaries and its relevancy when evaluating CCS in a climate policy perspective. Limiting factors like time perspective, geographical scope and technical and political levels of analysis might influence to what extent CCS is considered a climate policy instrument.

Having built the analytical foundation to evaluate the Norwegian empirical context, chapter 4 set off by introducing the empirical background on the Norwegian CCS commitment. Relevant Norwegian climate policy goals and obligations were thereafter elaborated, underlining their functions as part the sustainable development strategy. The chapter thereafter presented three different scenarios of the Norwegian CCS commitment. The different scenarios emphasized different system perceptions, to shed light on different aspects to Norwegian CCS strategy. One scenario examined the prospects of a full-scale CCS plant at Mongstad CHP. A second scenario addressed the TCM capture technology center. The final scenario discussed the ambition of a European CCS network with storage under the NCS.

Chapter 5 was the final analysis chapter. It evaluated the degree to which the Norwegian CCS effort, operationalized as the three scenarios in chapter 4 combined, could be understood as a "climate policy instrument" as defined in chapter 2 when looking at its political, economic and technical framework conditions. The main findings suggested that CCS has potential as a climate policy instrument primarily as an *end of pipe solution* in a single site perspective. Within these boundaries, a CCS equipped CHP Mongstad performs better than a reference BAU scenario. In a wider system perspective, where electricity from CCS-equipped power plants, substitutes more polluting alternatives CCS may also be regarded a *transitional measure.* Other conditions for this to apply are "closed loops" in cases where sequestered CO_2 is used for EOR purposes. CCS in not sustainable, however, as it merely provides a technological fix to a problem caused following exploitation of a finite resource. The decisive question to whether CCS may function transitionally towards sustainable development is whether fossil fuels will remain the main energy sources also in the coming decades. As an instrument to fulfill the Norwegian climate policy objectives, CCS comes into effect beyond the 2020 target – and at earliest to support the 2030 ambition. Materializing the CCS ambitions will require considerable public support, potentially at the expense of other GHG mitigation innovations. Before forcefully commercializing CCS, one should be aware what uncertainties in terms of energy futures and scenarios one gives answer to. For the reasons explained above, I question whether CCS is an effective means to underpin the sustainable development strategy. I also suggest that the measure used by that strategy to evaluate performance in the climate policy area is insufficient, as it does not pick up considerations as those presented above, but merely addresses the Kyoto target. As executed policies are results of winning coalitions, it is likely that the Norwegian CCS effort is not guided by concerns over climate change alone. It may therefore be timely to recall the two conditions for CCS to make sense in a climate policy perspective: a) GHG emissions reduction and b) continued fossil fuel consumption.

6.2 Methodological Issues

A study like this, where concepts are constructed and operationalized before being applied to evaluate a scenario based empirical setting, certainly encounters methodological challenges. This relates to the validity and reliability of the methods used. The most prominent of these aspects are addressed in the following.

6.2.1 Validity concerns

The present findings and conclusions are based on the analytical framework built, namely the climate policy instrument typology and the framework condition model for CCS implementation. First, for the construction of the climate policy instrument typology, the criteria on which it is based, are key. I could emphasize other criteria, say social and distributional aspects to climate policy instruments, had I used other theory as starting points. Also, prioritizing differently among the included chosen criteria, could affect the findings. A potentially more transparent approach could therefore be to weight the factors included in the typology using a quantitative measure. The more qualitative solution was chosen, however, in order to put focus on the qualitative distinctions between the different categories and criteria. Nevertheless, these are important aspect to take into account when assessing the validity of the findings at hand. As for the theoretical foundations this typology rests on, my role as a student of Industrial Ecology positions me in a certain discursive perspective, which may affect my perception of the data – both in terms of choices on theoretical sources and empirical data. I have accounted for these subjective aspects in chapter 2.8.

The same challenges apply for the model built on framework conditions for CCS deployment. Based on the theoretical approach, the data used in this text are constructed with political, economic and technical aspects to CCS deployment in mind. Taking on only these factors implies that other elements of potentially explanatory value are not given attention (Moses and Knutsen 2007). The debate on risks of leakages from CO_2 deposits has in practice been omitted, for instance. Not following up on this issue has in essence left the precautionary principle, a primary guideline in Norwegian environmental policy, out of out the scope of this text.[44] Taking such decisions have been necessary, however, out of concerns over focus stringency.

The chosen operationalizations of the addressed variables could also leave gaps. For example are comparative perspectives towards competing climate policy instruments and detailed technical assessments, found to be out of scope. Juridical aspects to operative regulations and technology standards are not addressed in detail either, as I aimed at presenting an overarching array of framework conditions that affect the Norwegian CCS strategy. This leaves less room for details, although that is often where the devil is found. “Overview versus detail” trade-offs are always present in these situations. Further, the relevant technical, political and economic framework conditions are not easily told apart in all instances. This applies in particular where economic framework conditions are seen as applied policy tools, as we saw in chapter 4. Unclear variable distinctions may affect validity aspects, making it challenging to report on the explanatory value of each variable.

[44] Arguably, lack of discussion on this topic is symptomatic for the Norwegian CCS context as a whole.

Understanding the three variables as independent gives a misguiding view on reality. That being said, a strict variable analysis was never the overall intention of the study. I focused on providing an analytical narrative on the Norwegian CCS context, where economic and political concept operationalizations are accounted for as possible, founded on the preliminary institutional perspective to political economy.

6.2.3 Reliability concerns

In terms of reliability, this study faces two challenges that both relate to predicting the future. First, it is hard to predict future energy trends. Building an analysis like this, or even strategic policies like CCS decisions, on such scenarios always come with a portion of uncertainty. On the other hand, decisions on the future will always suffer from limited information. Second, constructing CCS scenarios, as done in this text, should be done with caution. The data these are built on, describe an uncertain future. It is in this context worth highlighting that these sources to a large extent advocate CCS deployment and therefore risk downplaying down whatever challenges CCS in a climate policy perspective could encounter. This also goes for the other sources of data used, as well. CCS as climate policy is a fairly new and unexplored field. A consequence is that much of the existing material on the topic is published by actors with an enthusiastic take on the concept. This is why I have found support in literature on climate policy instruments outside the technocratic CCS realm when constructing the climate policy typology. Another problem when referring to studies on future projections, on for example the price of CO_2 capture or the EU ETS quota price, is that the assumptions put to ground in these studies, rarely match the context in which I apply them. Drawing conclusion based on such material will thus require care.

This being said, I consider the quality of the data consulted as satisfactory as the subject allows. I have addressed the topic as a policy initiative and treated it thereafter. I have drawn upon peer-reviewed academic where applicable. In order to ensure replicability, written sources are referred to also where information was originally brought to attention by the interviewees.[45]

Finally, could a different take on the research question be more successful? Yes and no. A comparative study between empirical cases could contrast the performance of CCS as a climate policy instrument in a Norwegian against its effectiveness somewhere else. Also systematically comparing CCS towards other climate policy instruments in Norway could have a similar effect. Yet, when bearing in mind the explorative, concept-building ambitions of this study, I consider this single case oriented approach to be well suited.

In total, when taking the concerns addressed above into account, I consider the established concepts and conclusions found as acceptable. Hopefully, they may render fruitful as beginning steps on this relatively immature topic, in terms of construction of concepts and analytical frameworks.

6.3 Concluding Remarks

I have aimed at addressing the effectiveness of CCS as a climate policy instrument in Norway. The present study may be considered as a contribution to the discussion on increased means-goals efficiency in Norwegian climate policy making. Although the research question takes on Norway in particular, could the developed framework conditions and system requirements hopefully be helpful when approaching other country-specific studies as well. The broader system perimeters described to be part of the Norwegian CCS context could widen the relevancy of the findings at hand. As a study on the performance of CCS in a climate policy perspective, the results found could therefore be of interest in other empirical settings also.

[45] The absence of explicit references to data obtain in the interviews is unfortunate in this context. A later edition of this text would probably have eliminated this problem.

In addition to shedding light on the research question, this text has identified related issues where more knowledge is needed. This goes in particular for the climate policy instrument concept and the role of technological solutions and innovation in that regard. The potentially competitive or symbiotic relationship between climate policy and other policy fields, and particularly energy policies, should be of interest for future study. Also the notion of system perimeters is worth investigating further. This text has contributed to the development of a conceptual analytical framework and policy analysis, but more detailed studies on the environmental performance of CCS in a Norwegian context are needed. Here could potentially the quantitative industrial ecology toolkit be helpful, in terms of life cycle assessments and indicator development.

Finally, and a bit one the sideline, how useful are really the energy and climate policy scenarios that largely define what are relevant policy actions? To what extent is the predicted energy future inevitable? We should learn to tell how future forecasts might serve particular interests. What are the agendas of those who look into the crystal ball? Given the attention that is increasingly given to CCS in the national and international climate policy discourse, the urgency of the climate change problem, and the considerable resources spent on materializing CCS, more research on its effects and character as a climate policy solution is welcome. As a well-meant advice in many situations in life, the following quote by Robert J. McKain may inspire us to take good decisions in climate policy making also:

Set priorities for your goals. A major part of successful living lies in the ability to put first things first. Indeed, the reasons most major goals are not achieved is that we spend our time doing second things first.

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Annex: Interview Guides

Interview: Øyvind Christophersen

6 April 2011

Senior advisor, Section for climate and energy, Department of climate and industry, Climate and Pollution Agency

CLIMATE POLICY TOOLS ***KLIMATILTAK***
What criteria should a climate policy tool fulfill? *Hvilke kriterier bør et godt klimatiltak innfri?*
CCS SCENARIOS ***CCS SCENARIER***
Given that national emission targets are in 2020 and a global peak of GHG emissions is recommended by 2025 in order to limit human induced climate change, will CCS arrive in time? *Gitt at nasjonale mål er innen 2020 og verdenspeak må være 2020-25, vil CCS komme tidsnok? (hva med kostnad/ tid/ unngått)*
MATERIALIZING CCS ***REALISERING AV CCS***
What is the role of the Climate and Pollution Agency and the Ministry of the Environment in conducting CCS as climate policy? *Hva er Klifs og MDs rolle i gjennomføringen av CCS som klimapolitikk?*
Hva is the current status of CCS in the UNFCCC, OSPAR, and the London protocol? *Hva er status i: UNFCCC, OSPAR, London protokollen?*
How important are CSLF, North Sea Basin task Force, ZEP and 4 Kingdom initiative for the interest in CCS? *Hvor viktige er CSLF, North Sea Basin Task Force, ZEP og 4 kingdom initiative for interessen for CCS?*
Which are the international political conditions for CCS activity in Norway: Can we expect that Norway continues doing CCS even if the concept is not widely accepted/ deployed internationally?

Hvilke er de internasjonale politiske betingelsene for CCS-aktivitet i Norge: Kan vi se for oss at Norge fortsetter med CCS selv om det ikke vinner aksept/ gjennomføres i stor skala internasjonalt?
CLOSING QUESTIONS ***AVSLUTTENDE SPØRSMÅL***
What would you like to say in addition to what I have already asked? *Hva vil du si i tillegg til det jeg har spurt om?*
Who else should I talk to? *Hvem burde jeg snakke med?*
What are typical misunderstandings on this topic? *Hva er typiske misforståelser om dette emnet?*

Interview: Aage Stangeland

5 April 2011

Special advisor, department for energy, Division for energy, resources and the environment, Norwegian Research Council

CCS SCENARIOS ***CCS SCENARIER***
Would we have seen CCS in Norway if it were not for climate political concerns? - *How important is EOR for Norwegian CCS deployment?* - *How important are sales of CO_2-free electricity to Europe?* - *Can CO_2 be used for anything else than pressure support in Norway?* *Ville vi sett CCS i Norge hvis det ikke var for klimapolitiske hensyn?* o *Hvor viktig er EOR for norsk CCS-utrulling?* o *Hvor viktig er salg av CO_2-fri elektrisitet til Europa?* o *Kan CO_2 brukes til noe annet i Norge enn trykkstøtte?*
Given that national emission targets are in 2020 and a global peak of GHG emissions is recommended by 2025 in order to limit human induced climate change, will CCS arrive in time?

Gitt at nasjonale mål er innen 2020 og verdenspeak må være 2020-25, vil CCS komme tidsnok?
How well mapped and characterized are potential deposits and infrastructure for CO_2 transportation in Norway? *Hvor godt kartlagt er deponier og infrastruktur for transport i Norge?*
When will we see a European CCS value chain with storage in the North Sea? *Når får vi se en europeisk verdikjede med lagring i Nordsjøen?*
Will the European CCS value chain with storage in the North Sea happen with or without EOR? *Europeisk verdikjede med lagring i Nordsjøen med eller uten EOR?*
What is the time perspective for using CCS in Norway? A transitional measure towards sustainable development or ensuring decade after decade of fossil fuel energy supply? *Hvor langt tidsperspektiv for bruk av CCS i Norge? Overgangstiltak mot bærekraftig utvikling eller flere tiår med energiforsyning?*
How broadly recognized are the different scenarios for Norwegian and European CCS and how set the agenda? Is there an agreed development? *Hvor "vedtatt" er de ulike scenariene for norsk og europeisk CO_2-håndtering og hvem setter agendaen? Finnes enighet om utviklingen?*
MATERIALIZING CCS IN NORWAY ***REALISERING AV CCS I NORGE***
What is meant by the term "commercializing" CCS in Norway? Related to a particular project or a full value chain including several capture sites? *Hva er kommersialisering av CO_2-håndtering i Norge? Stedspesifikt eller full verdikjede (som er flere punkter og felles transport)?*
Who are the most important actors for realizing CCS in Norway? *Hvem er de viktigste aktørene for realisering av CCS i Norge?*
What comprises current public support for CCS in Norway? *Hva er offentlig støtte til CCS i Norge i dag?*

How important is the CO_2 quota price for sparking more CCS projects than Sleipner and Snøhvit today and the coming years? *Hvor viktig er kvoteprisen for å utløse flere CCS-prosjekter enn Sleipner, Snøhvit og CHP i dag og de neste årene?*
Which are the main challenges for commercializing CCS in Norway? *Hva er hovedutfordringene for "kommersialisering av CO2-håndtering i Norge?"*
On the CLIMIT program plan:" Inexpensive CCS, prepare storage sites in the North Sea, improve post-combustion capture technologies." Previously focus on national power supply in the CCS debate, now more attention is given technology development – why is this? Is it really CLIMIT that decides Norwegian CCS realization targets? *CLIMIT programplan: "Billig CO_2-håndtering, forberede lagre i Nordsjøen, forbedre post-combustion? Kommersiell forankring av post-combustion i Norge?" Før egen strømforsyning – Nå fokus på teknologiutvikling - hvorfor? Er det egentlig CLIMIT som utfører norsk CO_2-håndteringspolitikk – beste* *programplan?*
On Norwegian political support: How can it be done better and what policy tool be used or scaled up? *Norsk politisk støtte: Hvordan gjøres bedre og hvilke policy virkemidler burde tas i bruk eller styrkes?*
Is the Norwegian CCS commitment long-term? Can it face stagnation after the Kyoto period is over? *Framstår satsingen langsiktig? Kan rammes av stagnasjon etter Kyoto?*
COSTS AND ECONOMY ***KOSTNADER OG ØKONOMI***
How much more expensive is CCS than other renewables now and in the near future? *Hvor mye dyrere er CCS enn andre fornybare nå og om kort tid?*
What is an acceptable cost for CCS? *Hva er en akseptabel kostnad for CCS?*
What is acceptable technology performance? *Hva er akseptabel teknologiytelse?*

What should a CO_2 quota cost in order to realize CCS? *Hva bør en kvote koste for å realisere CCS?*
How steep is the technology learning curve after the first CCS plant is built? *Hvor bratt ser en for seg at læringskurven er når det første anlegget er bygget?*
CLIMATE POLICY MEASURE ***KLIMATILTAK***
What are important indicators for measuring climate policy tools? *Viktige indikatorer å måle etter?*
What interests must a climate policy measure fulfil? *Hvilke interesser må et klimatiltak innfri?*
How well does CCS fit as climate policy? *Hvor godt passer CCS i Norge som ideell klimapolitikk her?*
CLOSING QUESTIONS ***AVSLUTTENDE SPØRSMÅL***
What would you like to say in addition to what I have already asked? *Hva vil du si i tillegg til det jeg har spurt om?*
Who else should I talk to? *Hvem burde jeg snakke med?*
What are typical misunderstandings on this topic? *Hva er typiske misforståelser om dette emnet?*

Interview: Eirik Frøhaug Swensen

11 April 2011

PhD student, Centre for Sustainable Energy Studies (CenSES), Norwegian University of Science and Technology (NTNU)

GAS POWER AND CCS DEPLOYMENT IN NORWAY ***REALISERING AV GASS OG CCS I NORGE***
Who are the main actors in the Norwegian natural gas approach? *Hvem er aktørene for gass-satsingen i Norge?*
Who are the most important proponents of gas power? How strong is the political support towards CCS as climate policy and how much is political prestige related to the Mongstad project? *Hvem er de viktigste pådriverne?* *Hvor sterk er den politiske støtten til konseptet som klimapolitikk, og hvor mye er Mongstad-prestisje?*
Why CCS in Norway? *Hvorfor CCS i Norge?*
What shall gas power from the different power plants be used for? *Can we expect more gas power plants in Norway if the "CCS mystery" gets solved quickly and cheaply?* *Hva skal gasskraften fra de ulike kraftverkene brukes til?* *Kan vi se for oss flere gasskraftverk om CCS-gåten løses fort og billig?*
What kind of infrastructure exists and what is planned for gas and electricity transportation from Norway? *Hva slags infrastruktur finnes og hva er planlagt for gass og elektrisitetstransport fra Norge?*
Norwegian political support for gas and CCS: What is special about the Norwegian policy toolbox? How can it be used better? *Norsk politisk støtte til gass og CCS: Hva er spesielt med det norske virkemiddelapparatet?* *Hvordan gjøres bedre og hvilke virkemidler burde tas i bruk eller styrkes?*
Can the gas power track and CCS face stagnation after the Kyoto commitment period expires? *Kan gass og CCS rammes av stagnasjon etter Kyotoperioden med usikkerhet i utslippsforpliktelser?*

How long-term are Norwegian gas reserves - can EOR help? *Hvor langsiktige er norske gassreserver – kan CO2-basert EOR hjelpe?*
Which are the international conditions for gas activity in Norway today? *Hvilke er de internasjonale betingelsene for gass-aktivitet i Norge?*
What comprises public support for CCS in Norway today? *Hva er offentlig støtte til CCS i Norge i dag?*
COSTS AND OTHER MEASURES ***KOSTNADER OG ANDRE TILTAK***
What is the price of gas power compared to renewable energy now and in the short term? *Hvor koster gass sammenliknet med fornybare nå og om kort tid?*
What other climate policy instruments threaten the Norwegian CCS track? *Hvilke andre klimapolitiske tiltak truer CCS i Norge mest?*
CLMATE POLICY TOOLS ***KLIMATILTAK***
What signifies good climate policy? *Hva kjennetegner god klimapolitikk?*
What criteria should a good climate policy measure fulfil? *Hvilke kriterier bør et godt klimatiltak innfri?*
How well does CCS fit as climate policy in Norway? *Hvor godt passer CCS i Norge som klimapolitikk?*
CLOSING QUESTIONS ***AVSLUTTENDE SPØRSMÅL***
What would you like to say in addition to what I have already asked? *Hva vil du si i tillegg til det jeg har spurt om?*
Who else should I talk to? *Hvem burde jeg snakke med?*

What are typical misunderstandings on this topic? *Hva er typiske misforståelser om dette emnet?*

Interview: Inger Østensen

14 April 2011

Deputy director, Section for CCS, Department for the climate, industry and technology, Norwegian Ministry of Energy and Petroleum

CCS SCENARIOS ***CCS SCENARIER***
Would we have seen CCS in Norway if it were not for climate political concerns? - *How important is EOR for Norwegian CCS deployment?* - *How important are sales of CO_2-free electricity to Europe?* - *Can CO_2 be used for anything else than pressure support in Norway?* *Ville vi sett CCS i Norge hvis det ikke var for klimapolitiske hensyn?* o *Hvor viktig er EOR for norsk CCS-utrulling?* o *Har CO_2 andre bruksområder i Norge enn trykkstøtte?*
Why is the section for CCS part of the Ministry for Energy and Petroleum and not the Ministry of the Environment? *Hvorfor ligger CCS-seksjonen under OED og ikke MD?*
Given that national emission targets are in 2020 and a global peak of GHG emissions is recommended by 2025 in order to limit human induced climate change, will CCS arrive in time? *Gitt at nasjonale mål er innen 2020 og verdenspeak bør være 2020-25, vil CCS komme tidsnok?*
How well mapped and characterized are potential deposits and infrastructure for CO_2 transportation in Norway? *Hvor godt klargjort er deponier og infrastruktur for transport i Norge?*
When will we see a European CCS value chain with storage in the North Sea? *Når får vi se en europeisk verdikjede med lagring i Nordsjøen?*

Will the European CCS value chain with storage in the North Sea happen with or without EOR? *Europeisk verdikjede med lagring i Nordsjøen med eller uten EOR?* *Klimapolitisk vanskelig med EOR?*
How can sales of CO_2 storage capacity happen between countries? As part of the EU ETS and UNFCCC? Can Norway earn good money on this? *Hvordan kan salg av CO_2-lager foregå? Som del av EU ETS og UNFCCC? Kan Norge virkelig bli rike på dette?*
How broadly recognized are the different scenarios for Norwegian and European CCS and how set the agenda? Is there an agreed development? *Hvor "vedtatt" er de ulike scenariene for norsk og europeisk CO_2-håndtering og hvem setter agendaen? Finnes enighet om utviklingen?*
MATERIALIZING CCS IN NORWAY ***REALISERING AV CCS I NORGE***
Who are the most important proponents of CCS in Norway? How strong is political support to the concept as climate policy and how much of that support is really about the Mongstad project specifically? *Hvem er de viktigste pådriverne for CCS i Norge? Hvor sterk er den politiske støtten til konseptet som klimapolitikk, og hvor mye handler om Mongstad spesifikt?*
What comprises current public support for CCS in Norway? *Hva er offentlig støtte til CCS i Norge i dag?*
What is the time perspective for using CCS in Norway? A transitional measure towards sustainable development or ensuring decade after decade of fossil fuel energy supply? *Hvor langt tidsperspektiv for bruk av CCS i Norge og internasjonalt? Overgangstiltak mot bærekraftig utvikling eller flere tiår med energiforsyning?*
How important is the CO_2 quota price for sparking more CCS projects than Sleipner and Snøhvit today and the coming years? *Hvor viktig er prisen på CO_2 for å utløse flere CCS-prosjekter enn Sleipner, Snøhvit og CHP i dag og de neste årene? Samme kvotepris i Norge som i EU ETS?*

Which are the main challenges for commercializing CCS in Norway? *Hva er hovedutfordringene for "kommersialisering av CO2-håndtering i Norge"?*
Are the operative regulations for building a CCS value chain in place? *Er de operative reglene klare for å bygge verdikjede i Norge? Lov for rørledninger og lagre i Norge?*
On Norwegian political support: How can it be done better and what policy tool be used or scaled up? *Norsk politisk støtte: Hvordan gjøres bedre og hvilke virkemidler burde tas i bruk eller styrkes?*
How will CO_2 stored from CCS-plants be reported in national GHG inventories? *Hvordan vil CO_2 lagret fra CCS-anlegg rapporteres i nasjonale regnskap?*
Which are the international political conditions for CCS activity in Norway: Can we expect that Norway continues doing CCS even if the concept is not widely accepted/ deployed internationally? *Hvilke er de internasjonale politiske betingelsene for CCS-aktivitet i Norge: Kan vi se for oss at Norge fortsetter med CCS selv om det ikke vinner aksept/ gjennomføres i stor skala internasjonalt?*
COSTS AND OTHER MEASURES ***KOSTNADER OG ANDRE TILTAK***
What is an acceptable cost for CCS? *Hva er en akseptabel kostnad for CCS?*
How steep is the technology learning curve after the first CCS plant is built? *Hvor bratt ser en for seg at læringskurven er når det første anlegget er bygget?*
What is acceptable technology performance? *Hva er akseptabel teknologiytelse?*
What other climate policy instruments can take resources away from the CCS strategy – renewables, efficiency improvements? *Hvilke andre klimapolitiske tiltak truer CCS i Norge mest - fornybar energi, effektivisering?*

CLIMATE POLICY TOOLS ***KLIMATILTAK***
What criteria should a good climate policy tool fulfill? *Hvilke kriterier bør et godt klimatiltak innfri?*
How well does CCS fit as climate policy? *Hvor godt passer CCS i Norge som ideell klimapolitikk her?*
CLOSING QUESTIONS ***AVSLUTTENDE SPØRSMÅL***
What would you like to say in addition to what I have already asked? *Hva vil du si i tillegg til det jeg har spurt om?*
Who else should I talk to? *Hvem burde jeg snakke med?*
What are typical misunderstandings on this topic? *Hva er typiske misforståelser om dette emnet?*