IMPROVING DECISION-MAKING ON CARBON CAPTURE AND STORAGE IN ENERGY-INTENSIVE INDUSTRIES IN THE EU

Improving Decision-Making on Carbon Capture and Storage in Energy-Intensive Industries in the EU

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PREFACE

These are the last sentences of my thesis, my master program and of my study career. All the time and efforts I have spent in the past eight years on my studies are supposed to culminate in this work. Sometimes it felt like I was writing something revolutionary, many other times I balanced on the thin line between useful or scientific statements and meaningless nonsense. Although the overall process has been fast, but I have struggled for many weeks in the beginning to find a relevant and do-able research topic and at the end to find relevant conclusions. The help of Eefje Cuppen, my first supervisor, has been vital and therefore I would like to express my sincere gratitude here. I would also like to thank Daniel Scholten and Hans de Bruijn for their critical reflections on what I was doing.

I have had the opportunity to experience how difficult it is for our society to reach agreements on what is so essential to all of us: the global environment. Unfortunately, it has not made me optimistic about our ability, as a society, to act on such a large scale. It has also provided me with insights on what role I want to play in this and I am excited soon starting a new chapter of my life. For offering this opportunity to me and for their useful advice I would like to thank the people from Triarii, in specific Robert van der Lande en Gert-Jan van der Panne.

Finally, I would like to thank my family and friends for their support and understanding. I might not have been the best company in the recent weeks. It seems I have felt some stress in these weeks for the first time of my life. It is time to finish off.

Amsterdam, August 2014

Jacob de Jongh

SUMMARY

Carbon capture and storage (CCS) is a CO2 emission mitigation technology that can be used to reduce emissions from both fossil-fueled power plants and energy-intensive industries (EnIIs) such as steel, refining, cement and chemicals. CCS is one of the few technologies that can reduce the EnIIs' emissions to the extent required to meet the European Union's (EU) emission reduction targets. Decision-making on CCS in EnIIs in the EU faces difficulties due to the resource interdependencies between actors, conflicting interests and different views on problems and solutions. The main research question addressed in this study is how decision-making on CCS in EnIIs in the EU can be improved.

Although technologies for the three steps of CCS (capture, transport and storage) are available, deployment in the EU's EnIIs is stalling. The current policy framework is not suitable for bringing CCS in EnIIs further. The EU Emissions Trading Scheme does not provide the incentives for industries to invest in CCS projects and support schemes are limited. A policy redesign has to take global competition into account: when incurring extra costs for CCS upon the EnIIs, a push factor is created for leaving the EU and relocating their activities to parts of the world with less stringent emission abatement environments. Legal issues related to transport and storage of CO2 remain as well. The political context is shaped by social reluctance for the technology. Opponents of the technology doubt the role CCS can play in safe and sustainable EnII emissions reduction.

In this context of resource interdependencies, conflicting interests and different frames on CCS in EnIIs a process management approach can bring decision-making further. Process management focusses on resource interdependencies and conflicting interests and proposes a number of governance strategies. A good process design entails an open process, protection of stakeholders' core values, incentives for decision-making progress and quality of the content of the taken decisions. The drawbacks of process management can be mitigated by including stakeholder frames into the design. This can lead to better reduction of information uncertainties, a more comprehensive understanding of the problem, increased support for decisions, democratic legitimacy and increased opportunities for a deliberative process.

Stakeholder frames have been measured, using Q methodology, in order to show how the inclusion of frames in a process design can improve decision-making. Q methodology systematically maps the perspectives stakeholders have by asking them to sort a number of statements related to barriers, drivers, problems and solutions for the development and deployment of CCS in EnIIs. In this study 14 respondent were asked to rank 31 statements on a quasi-normal distribution. They were also asked to give their considerations and arguments while making the sort. From the analysis it was concluded that four frames exist among stakeholders:

1) It's the suffering industry, stupid!

   In this frame the cause of the lack of development is that the European industry is suffering from decreasing profits due to lower demand, higher energy costs and international competition. At this moment we cannot ask the industry to battle CO2 emissions, because they simply will not be able to pay for it. If we want to progress CCS in EnIIs, either international climate agreements have to be reached or tax payers will have to pay it.

2) It's the lack of cooperation stupid!

International competition means that it is hard for the European industry to reduce emissions. But another main issue is that stakeholders are not cooperating well. Environmental NGOs and politicians should be more outspoken in favor of CCS in EnIIs and we need industry wide cooperation. An open dialogue and creating trust between the industry and policy-makers is important.

3) It's the policy, stupid!
   International competition is not the main issue, it is the lack of a functioning EU policy framework. The key issue is that the EU's Emission Trading Scheme (ETS) is not incentivizing EnIIs to do CCS. Maybe we need another mechanism or improve the current mechanism. Politicians are to take the lead in shaping the right policies to make CCS happen.
4) It's the whole package, stupid!
   The EU ETS is indeed not functioning well, stakeholder cooperation could be improved and the industry is facing international competition, but social acceptance is an issue as well. We cannot bring CCS in EnIIs further if we not address all of these four issues.

Other conclusions that can be drawn from the interviews include:

- social acceptance is not one of the key issues in CCS for EnIIs according to many stakeholders;
- there is a strong distrust between some EnIIs and some Non-Governmental Organizations (NGOs);
- Directorate-general (DG) Industry & Enterprise of the European Commission is technology-neutral and considers CCS as just one of the emission reduction technologies for the EnIIs;
- CO2 utilization is not an important driver for CCS in EnIIs to many stakeholders.

The distribution of stakeholders among the frames is not dependent on stakeholders' affiliation (industry, NGO, policy-maker). This leads to the conclusion that a process design based on stakeholders frames does look different than a standard process design in which stakeholders are selected based on affiliations.

When combining the theoretical process management approach enriched with stakeholder frames with the empirical data on CCS in EnIIs and frames stakeholders hold on CCS in EnIIs a number of conclusions can be drawn about improving the decision-making process on CCS in EnIIs:

- Currently, a decision-making process in which relevant stakeholders discuss the governance of CCS in EnIIs is lacking;
- the European Commission is in the best position to initiate such a process;
- participation is required by a broad range of stakeholders that should be selected based on their resources and interests, but also based on the frames they hold;
- reluctant stakeholders can be convinced to join to process by framing the decision-making issue in a broad way;
- DG Industry & Enterprise should make a more explicit choice for CCS in EnIIs and join the process;
- public support could be increased by demanding that all stakeholders frames are considered in the argumentation for decisions;

- a broad multi-issue agenda should be created with a focus on international competition, stakeholder cooperation and a policy framework for CCS in EnIIs, social acceptance is to a lesser extent important to stakeholders;
- deliberation and social learning should be incentivized by making frames explicit in the protected lower organizational structures of the process; the communalities in the frames creates opportunities for that.

The main contribution of this study is that it shows that incorporating stakeholder frames in a process management approach can lead to improving decision-making on unstructured problems in which there are resource interdependencies, conflicting interests and different views on problems and solutions.

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LIST OF ABBREVIATIONS

BECCS	Bio Energy with CCS
CCS	Carbon Capture and Storage
CEF	Connecting Europe Facility
CFA	Centroid Factor Analysis
EC	European Commission
ECN	Energie Centrum Nederland
EEPR	European Energy Program for Recovery
EERP	European Economic Recovery Program
EOR	Enhanced Oil Recovery
EnII	Energy Intensive Industry
ETP	European Technology Platform
ETS	Emission Trading System
EU	European Union
FIT	Feed-In Tariff
GCCSI	Global Carbon Capture and Storage Institute
GHG	Greenhouse Gas
IEA	International Energy Agency
NER300	New Entrants Reserve 300

NGO	Non-Governmental Organization
NIMBY	Not In My Back Yard
PCA	Principal Component Analysis
R&D	Research & Development
SCCS	Scottish Carbon Capture and Storage
UNIDO	United Nations Industrial Development Organization
ZEP	European Technology Platform on Zero Emission Fossil Fuel Power Plants

CHAPTER 1: INTRODUCTION

1.1 RESEARCH DEFINITION

1.1.1 PROBLEM EXPLORATION

In order to meet its target of a maximum 2ºC rise in global mean temperature the EU's mission is to reduce the emission of CO2 by 50 to 85% by 2050 (Solomon et al., 2007). Part of those emission reductions are expected from energy-intensive industries (EnII) such as steel, cement, chemicals and refineries (EC, 2011). This could be done by decreasing production, relocating industrial production to areas outside the European Union (EU), or mitigating emissions. Since both decreasing production and relocating the industry is undesired from a social-economic perspective, emission mitigation is a must in these industries in order to meet reduction targets, and even more important, limit the negative effects of climate change.

CO2 emission mitigation in EnII can only partially (up to between 20% and 40% of the needed 80%) be realized by increasing efficiency through recycling, fuel substitution, energy recovery and application of the best available technologies (IEA/UNIDO, 2011; ÖKO, 2012; ZEP, 2013a). Carbon capture and storage (CCS) is a technology that can be used to reduce emissions much further. It comprises the capture of CO2 at emission sources, the transport of the CO2 to storage facilities and the permanent storage of the gas. Many, among which the European Commission, therefore conclude that CCS is an indispensable technology in meeting the EU's emission reduction targets in EnIIs (EC, 2014).

Currently, only 60 large scale integrated CCS projects are or have been in operation, under construction or initiated globally, of which 26 in energy-intensive industries. Eight of all CCS projects are in the EU. Only one of those is in high emission industries[1]. There is a contrast between the need for CCS in EnIIs industries in the EU and the current state of its development.

There is a clear gap between the experienced situation (high emissions from EnII) and the desired situation (mitigating a large part of the EnIIs' emissions by deploying CCS). It should be stated clearly here tough, that, although many recognize the importance of CCS in EnII, there is strong opposition against CCS from environmental non-governmental organizations (NGOs), local citizens and political entities. Clearly, this already leads us to an understanding to why the deployment of CCS in EnII is difficult. The social and political acceptance of CCS in EnII and CCS in general is of great importance for understanding it, but there are more dimensions to be considered.

In many environmental issues we can find environmental NGOs and industries on opposite sides of the spectrum. For CCS this situation is much more complex. Many industries are not in favor of CCS either, just like some NGOs. Partially because they realize the topic is sensitive to public opposition, but also for economic reasons. Applying the technology to existing or new industrial facilities increases production costs. This either reduces the industries' profits (explaining their reluctance) or increases consumer prices if industries are able to incorporate the costs of CCS in consumer prices. This can only be done if all firms would do this due to the competitive nature

[1] http://www.globalccsinstitute.com/data/status-ccs-project-database

of the EnII markets. If only the EU's EnII would increase consumer prices, consumers would stop buying their products and buy products produced other parts of the world. The EU's EnIIs are struggling already with international competition from regions of the world that have a more favorable production environment and therefore they have difficulty with paying for CCS.

So why would the EU industry deploy CCS if it either reduces profits or decreases market shares? There are policies that incentive firms to behave differently than they would have done without these policies. These incentives such as the EU Emission Trading Scheme (EU ETS) have the potential to make the costs of capturing and storing CO2 lower than the cost of emitting CO2. Profit optimizing firms would then choose to deploy CCS. But they can also choose to move their production facilities to region of the world with less restrictive emission reduction policies: carbon leakage. A way out could be to have global policies that provide industries with the incentive to reduce their emissions. Here we enter into the area of international trade relations and politics. And there are more aspects to CCS: technological, legal, social, political, environmental and economic. This will elaborated upon in chapter two.

1.1.2 PROBLEM DEFINITION

Why is CCS in EnIIs not happening? What should become clear from the introduction is that in order for an action related to CCS in EnIIs to be successful joined action is required. Actors have limited resources and are dependent on each other's resources and therefore they are interdependent. Secondly, actors have different and sometimes contradictory interests which makes it hard to act jointly. Thirdly, it is unclear which of the elements of CCS in EnII is most important in determining CCS in EnIIs' progress. There are different perspectives on reality here, actors use different frames to understand reality. Some might consider market imperfections crucial, while others think social acceptance will be key. Different perspectives on reality also lead to different ideas of solutions. These three characteristics of CCS in EnIIs (resource interdependencies, diverging interests and different actor frames) make that the decisions needed to develop CCS in EnIIs do not come about: there is a decision-making problem. This study addresses the decision-making on CCS in EnIIs in the EU.

1.1.3 RESEARCH QUESTION

The decision-making in CCS in EnIIs is characterized by resource interdependencies, diverging interests and different stakeholder frames. As will be shown a process management approach can be suitable to provide insight and practical design and management recommendations for such a decision-making process. It could be further enriched, though, when adding also stakeholder frames. This leads to the following research question:

> *How can process management, enriched with stakeholder frames, be used to improve the decision-making on carbon capture and storage in energy-intensive industries in the European Union?*

The sub questions are as follows:

I. *What does the CCS in EnIIs system look like?*

The answer to this question is a broad empirical exploration of the field of study: CCS in EnII. By using the concepts actors, technologies and institutions the complexity of CCS in EnIIs will be made clear. It leads to a conclusion on why we need to study decision-making on this matter.

II. *Why and how can process management help in improving decision-making on CCS in EnIIs?*
Once it has been made clear why decision-making on CCS in EnIIs needs to be studied in this question the best fitting decision-making model has to be identified. It will be theoretically argued why process management can help in the case of CCS in EnIIs and how it could be enriched including also stakeholder frames.

III. *What frames can be identified that stakeholders use to understand CCS in EnIIs?*
As identified in the last question process management enriched with stakeholder frames can facilitate decision-making in CCS in EnIIs. In this question these frames will be empirically researched using Q methodology.

IV. *What do process management and stakeholders' frames teach us on how to manage decision-making on CCS in EnIIs?*
In this final sub question the model of process management and stakeholders' frames will be used to analyze how decision-making on CCS in EnIIs could be improved.

Finally the main research question can be answered, the answer is both empirical in the sense that it includes recommendations for decision-making on CCS in EnIIs, and theoretical, in that it concludes about the value of including stakeholder frames in process management

1.1.4 BOUNDARIES

The subject of this study is decision-making on CCS in energy intensive industries. It is therefore not a technical study, rather, it is social-scientific study. Although some aspects of the technology should be considered for a proper understanding of decision-making on the technology, it is not the objective of this study to go into the technological debate.

The geographical boundary of the object of study is the European Union, although the international context will be considered sometimes. Since Norwegian institutions play a key role in the EU decision-making arenas on CCS, these institutions are included in the study. As will become clear the EU is a relevant geographical boundary because the development of CCS in the EU is stalling according to many. Secondly, decision-making on issues such as CCS in EnII (and environmental issues in general) typically takes place on a scale level such as the EU: policy mechanisms are implemented at the EU level and stakeholders are organized at the EU level.

The industries that are studied are energy-intensive industries. This term is somewhat misleading in that it suggests that energy intensity is the selection criterion for considering an industrial sector part of the energy intensive industries. The actual criterion is not energy intensity but greenhouse gas emission intensity or greenhouse gas production. Concepts like emission-intensive industries or high emission industries therefore better describe these industries. It should be understood that these industries emit CO2 because of their energy consumption but also due to the nature of the industrial process: the key part of the process is often to decarbonize a resource and by doing that producing CO2. Even if all of the energy they consume would be produced without emissions, the industries would still emit CO2 from the industrial process, so called process-emissions. It is therefore not the energy consumption alone that determines the emission.

Still, the decision has been made to use the term energy-intensive industries in this study, because it is the term that is used most frequently in both decision-making arenas (industries, NGOs, policy-makers) and scientific publications. The abbreviation EnII is used for energy-intensive industry and EnIIs for the plural. EnIIs that are considered in this study are steel, refining, chemical and cement. These four industrial sectors are by far the largest emitters and are in many studies considered the most important EnIIs. Some conclusions of this study might be valid for other EnIIs such as glass and pulp and paper as well.

1.2 RELEVANCE

1.2.1 SOCIETAL RELEVANCE

In general, the studying the abatement of CO2 emissions has a societal relevance. There is general consensus amongst scientist that human-induced CO2 emissions are the main contributor to the enhanced greenhouse effect creating climate change that poses all kind of risks to nature and human kind. To prevent or reduce the effects of climate change society therefore has to abate CO2 emissions. Reducing these emissions might be one of the biggest challenges that society has had, well-illustrated by the complicated process of reaching international climate agreements.

Decision-making on CCS in EnIIs shares characteristics with other environmental decision-making issues: contrasting views and interests while great dependency on each other’s contribution. Therefore, a greater understanding of decision-making on CCS in EnIIs might bring us further in comparable and related decision-making issues.

Understanding of decision-making on CCS in EnIIs has also a relevance itself: it is unlikely that emission from EnIIs can be significantly reduced by other technologies than CCS. If we expect that part of our emissions reduction has to come from EnIIs, we need to accept CCS as a major technology and therefore study its problematic decision-making.

1.2.2 SCIENTIFIC RELEVANCE

This study aims to modestly contribute to the theorizing on decision-making. In specific it attempts to show the value of a process approach for complex decision-making issues in which interests and frames are divergent and actors interdependent due to the resource distribution. It also tries to illustrate how a process management approach can be enriched by including frames or world views in addition to actors’ interests and resources in a process management design. As will be discussed in chapter 3 including frames in a process management approach can lead to reduction of information uncertainty, enrichment of problem definitions and solutions, support for decisions, democratic legitimacy and opportunities for deliberative decision-making. In this way a process approach including frames can lead to better decision-making.

1.3 RESEARCH OUTLINE

The next chapter, the system description, will further describe what issues occur in CCS in EnIIs. It starts with a short introduction of the concepts actors, technologies and institutions that will be used to structure the chapter. This chapter is the answer to the first research question and it should lead to insights on what issues decision-making should take place and how resource dependencies, diverging interests and different stakeholders' frames complicate decision-making on these issues.

Chapter 3 gives the theoretical framework for decision-making. In that chapter it will be argued why CCS in EnIIs can benefit from a process management approach. Furthermore it discusses pitfalls on process management and how stakeholder frames can be used to enrich the model. This chapter can be seen as the answer to the second sub question.

Chapter 4, consequently, describes which methods are used to come to an answer to the third research question. It describes Q methodology as the method used to find stakeholder frames.

Chapter 5 can be seen as the answer to the third research question. It describes the results of the Q methodology: stakeholder frames.

In chapter 6, analysis, an answer will be given to the last sub question on what process management and stakeholder frames can teach us about CCS in EnIIs.

In chapter 7 conclusions will be drawn about the case of decision-making on CCS in EnIIs and on the theoretical part of this study: the enrichment of process management with stakeholder frames.

Chapter 8 contains a discussion of several aspects of this study: theoretical, methodological and practical.

CHAPTER 2: THE SOCIO-TECHNICAL SYSTEM OF CCS IN ENIIS

This chapter describes all relevant aspects of the socio-technical system of CCS in EnIIs. It explains the complexity of the matter: it analyzes the resource interdependencies between actors, the different objectives that actors have and the different views they have on what potential solutions are to the issues. Therefore, it can be used as a starting point to understand why a process management approach is needed to guide decision-making on CCS in EnIIs, as will be explained in chapter 3. Finally, the elements described in this chapter will be used as input for the Q methodology as described in chapter 4 and 5.

This chapter starts with a short theoretical section on socio-technical change to understand why an understanding of actors, technology and institutions are all needed to gain insight in CCS in EnIIs. Consequently, the literature study methodology will be explained in short that is used for this chapter. Then the actors, technologies and institutions that are relevant to CCS in EnIIs are outlined.

A framework that is often used for environmental issues such as CCS in EnII is that of socio-technical systems. There is a broad literature of socio-technical change for which the base can be found in system theories. The foundations of the system approach lay in engineering sciences and operation research which explains its largely rational-technical nature (H. De Bruijn & Herder, 2009).

When exploring CCS in EnIIs from a system-perspective the question arises what the system comprises? What are the components or subsystems of the system? What are the system boundaries? Clearly, CCS has to do with technology, therefore technological components will have to be included in the system boundaries, but CCS in EnIIs cannot be fully understood when only considering technical aspects, rather it should be understood in its wider environment. As can be understood from the introduction (chapter 1) CCS technology is strongly connected to economic, political and social aspects and therefore those should also be included within the system. Such a system could be called a socio-technical system in which technical systems are interrelated with political, social and cultural institutions (Stephens & Jiusto, 2010). 'Socio-technical systems consist of a cluster of elements [or entities], including technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and supply networks (Geels, 2005)'.

Most authors identify three structural elements in socio-technical systems: actors, technologies and institutions (Suurs, 2009). Actors involve any organization or individual contributing to the emerging technology, either directly or indirectly, through choices and actions (Suurs, 2009). Actors have resources, interests and frames through which they view the system (see for a further discussion on this section 3.1). Technologies consist of artefacts and the technological infrastructure including cost structures, safety and reliability. Institutions, finally, can be defined as the rules of the game in a society, or more formally, the humanly devised constraints that shape human interaction (Suurs, 2009). In the following sections the concepts of actors, technologies and institutions will be used to describe CCS in EnIIs.

The first sub question '*What does the CCS in EnIIs system look like?*' will be answered by reviewing the relevant studies in the issues and interviews with experts in the field of CCS. Loosely the framework of socio-technical change is being used here, meaning that the concepts actors, technologies and institutions define what should be in, and what should be left out of the analysis. The articles used in this literature review have been found using databases such as Library of Congress, LISTA, PubMed and Web of Science. Search terms that were used include carbon capture and storage, social acceptance, energy intensive industries, high emission industries, policy incentives, carbon leakage and economic policies amongst many other terms. For the technology part no attempt was done to be inclusive of all literature: a number of sources were used in order to analyze the development barriers CCS faces without going into too much technical details. This chapter serves as an analysis of the economic, social, legal and environmental barriers for CCS in EnII, rather than following the technological debate. Next to published articles, reports of the European Technology platform on zero emission fossil fuel power plants (ZEP), the International Energy Agency (IEA), the United Nations Industrial Development Organization (UNIDO), the Global CCS Institute (GCCSI), the Öko-institut, the EC and the Scottish CCS (SCCS) and books were used on recent CCS developments. Clearly, much more literature is available on CCS in power than on CCS in EnII. In addition to written sources, semi-structured interviews were used with experts on CCS in general and CCS in EnII in particular. The experts were affiliated with the energy industry, the oil and gas industry, NGOs or research organizations. The full list of interviewees can be found in appendix 1, the interview protocol can be found in appendix 2. Questions included in the interviews were mainly related to barriers, drivers and policies for CCS. For the actor analysis the websites of relevant stakeholders were also used.

2.1 ACTORS

In this paragraph an overview will be given of the main actors, their resources and interests in the decision-making on CCS in EnIIs in the EU. The analysis of the frames of the different actors will follow in the next chapters. In Table 1 the important stakeholders can be found grouped by affiliation.

ACTORS	INTERESTS	RESOURCES
STEEL INDUSTRY COMPANIES (ArcelorMittal, Tata Steel, ThyssenKrupp, Voestalpine Stahl, Outokumpu, SSAB)	Profits. Competitive advantage. Corporate image. Favorable legislation.	Knowledge on technology and costs. Employer of many jobs. Financial resources.
REFINING COMPANIES (Shell, BP, Total, Statoil, Repsol, ENI)	Profits. Competitive advantage. Corporate image. Favorable legislation.	Knowledge on technology and costs. Employer of many jobs. Financial resources.
CEMENT COMPANIES (Heidelberg cement, Lafarge, Italcementi)	Profits. Competitive advantage. Corporate image. Favorable legislation.	Knowledge on technology and costs. Employer of many jobs. Financial resources.
CHEMICAL COMPANIES (Linde, BASF, Bayer, Air Liquide, Yara, AkzoNobel)	Profits. Competitive advantage. Corporate image. Favorable legislation.	Knowledge on technology and costs. Employer of many jobs. Financial resources.
NGOS		

Greenpeace	Reduce CO2 emissions without CCS.	Public support. Network.
(WWF, Bellona, E3G,Friends of the Earth)	Reduce CO2 emissions.	Public support. Network.
EQUIPMENT MANUFACTURERS		
(Siemens, Alstom)	Profits. New markets.	
EUROPEAN GOVERNMENT AGENCIES		
Directorate-General Research & Innovation	Technological development	Financial resources.
Directorate-General Climate Action	Reduce greenhouse gas emissions	Legislation. Financial resources
Directorate-General Industry & Enterprise	Economic development & employment	Financial resources.
RESEARCH INSTITUTIONS		
(ECN, SINTEF, TNO, Öko-institut)	Increase research budgets. Technological development.	Knowledge on technology.
NATIONAL GOVERNMENTS		
(UK, Norway, Germany, Netherlands, Spain, France, etc.)	Employment. Emission reduction. Government expenditure.	Financial resources. Legislation. Influence European Commission.
INDUSTRIAL ASSOCIATIONS		
(EUROFER, EUROPIA, CEMBUREAU)	Ensure favorable policies for industrial members.	Support from industrial members. Network.
OTHER		
(Zero Emissions Platform, Global CCS Institute, Scottish CCS, CCS Association, International Energy Agency)	Enable CCS for the industry.	Official advisory status (some actors). Network.

Table 1: Stakeholder analysis

The stakeholder analysis shows that different stakeholders have different and sometimes contradictory interests. While the industries' main objectives is to ensure or increase their profits, environmental NGOs want to realize lower emissions. Therefore, organizing cooperation between the two is not straightforward. There is a need for cooperation though, since they are dependent on each other's resources to realize progress. As will be further argued in the next chapter this induces the need for process management.

2.2 TECHNOLOGICAL ASPECTS

This section will introduce the technological aspects of CCS in EnIIs: the capture, transport and storage technologies, the related costs and the state of project development.

2.4.1 CCS TECHNOLOGY

Although the name suggests otherwise, CCS is a technology comprising three distinguishable steps. First, carbon dioxide has to be captured from emitters: large industrial sites such as power stations or other industrial sites, also called industrial point sources. Since it is rare that industrial point sources are located nearby potential storage facilities the second phase is to transport the CO2 to storage sites. Finally, the gas will have to be permanently and safely stored (ZEP, 2013a). Within the scope of CCS storage refers to geological storage rather than biological or chemical storage (Stephens, 2006). This paragraph will summarize the most important aspects of CCS technology.

Capture technologies

Due to the very different nature of the industries potential capture technologies are numerous. Not all of those will be discussed elaborately since that is beyond of the scope of this research, but a general overview will be given of them. In some industrial processes CO2 is already isolated as part of the production process resulting in a high enough concentration of CO2 in the flue gas to transport it directly. In most industrial processes the flue gas does not contain the high levels of CO2 needed for economically feasible transportation and the gas will have to be enriched. Technologies for extracting CO2 from the air have been available for a while: in submarines CO2 is directly captured from the air in order to keep the oxygen percentage high enough. Direct capture of CO2 from the atmosphere is currently very expensive and therefore cannot contribute significantly to reduce the abundance of CO2 in the atmosphere (Stephenson, 2013). Several other capture technologies are available for extracting CO2 from higher density gasses such as those emitted by industrial point sources. These technologies can be categorized as post-process, pre-process and oxyfuel (IEA/UNIDO, 2011).

Pre-process carbon capture that can be applied to coal-fired power stations or other industrial emitters that use carbon-containing fossil fuels or biomass entails the transformation of the fuel into hydrogen and CO2 before the industrial process (IEA/UNIDO, 2011). The hydrogen can then be used as fuel after separation from the CO2 and the concentration of the remaining CO2 will be high enough for transportation (Meadowcroft & Langhelle, 2009). Post-combustion entails the separation of CO2 from the other flue gases (mostly N2) at the end of the industrial process. This can be done by a chemical process using an amine solvent. The solvent extracts CO2 from the other gasses, after cooling the solution the CO2 and the solvent are separated. Since the solvent can only partially be reused this process requires a continuous supply of solvent. Physical separation could provide an alternative, it uses a membrane instead of a solvent and is therefore more sustainable. A third technology is oxyfuel carbon capture; fuel is burned in an oxygen rich environment (without N2) leading to mainly CO2 as product (Stephenson, 2013). After removal of particulates and contaminants this gas is ready for transport (IEA/UNIDO, 2011). Although these technologies have not been used for commercial CCS, they have been applied on a small scale for decades (ZEP, 2013a).

Transport technologies

The transport of CO2 is most likely to be done by pipelines, although liquefied CO2 shipping could be more cost effective in some instances for distances > 1000 km or over large bodies of water. Rail and road transport will only be feasible for small scale specialist applications (Boot-Handford et al., 2014). Pipeline transport of CO2 is already being used in many industrial processes: a 5,000 km CO2 pipeline network has been used for Enhanced Oil Recovery in the US for 30 years (ZEP, 2013a). Experience with ship-based transport is far more limited (Boot-Handford et al., 2014). Although the technology is available, the planning of building these pipelines is not straightforward. To keep the costs as low as possible, both the routes between different industrial point sources and storage facilities and the capacity of the pipelines should be carefully planned and coordinated (paragraph 2.2.1) (Mikunda et al., 2011; Stephenson, 2013).

Storage technologies

Three main options for storage of CO2 have been identified: deep saline aquifers (salt-water bearing rocks), depleted oil and gas fields and deep unmineable coal beds (ZEP, 2013a). CO2 is trapped at a depth of at least 800m under pressure and temperature conditions such that the CO2 is liquid. The trapping can be either physically or chemically in a porous formation, while above this formation there should be a layer of impermeable rock. Trapped CO2 can stay in these reservoirs for hundred thousands of years (Nicol et al., 2009). The storage of CO2 is the step that harbors the most safety and environmental risks (Boot-Handford et al., 2014; Stephenson, 2013). It is important to elaborate on the issue of technical risks since, as with every novel technology, social acceptance of CCS is strongly related to actual and perceived risks (for more on social acceptance see paragraph 2.2.2) (Bradbury, Greenberg, & Wade, 2011; G. Singleton, Herzog, & Ansolabehere, 2009). The main technical risks that can be identified are the escape of gaseous CO2 into the atmosphere or the escape of CO2 as aqueous solutions causing biological risks and the physical displacement of material inducing seismic activity (G. R. Singleton, 2007). Amongst experts these risks are generally not considered high probability nor high impact, especially compared to the environmental risk of not deploying CCS (Boot-Handford et al., 2014). They also have a strong site-dependency, therefore the best risk reduction measure is to find storage locations that bear very small risks (G. Singleton et al., 2009). The problem is that this requires proper selection procedures and further institutional capacity building and coordination. In this way the technical risks partially translate into governance risks (De Coninck et al., 2009). All this does not mean that there is broad agreement on risks: some environmental NGOs such as Greenpeace consider CCS as too risky (Rochon et al., 2008).

2.4.2 COSTS

For every low-carbon technology costs is one of the central issues. In the case of CCS this is currently highly uncertain due to the relative low level of development: the current costs are much higher than the predicted costs for when the technology is widely deployed, but how much the costs will decrease is uncertain (Scrase & Watson, 2009).

Capture costs

The cost of CCS comprises the cost of capture, transport and storage. These costs consist of the costs of additional energy usage in the different steps of CCS (up to 40%), the construction of new facilities and infrastructure and extra costs for maintenance and monitoring in CCS operation. The costs of capturing CO2 differs between technologies and industries. In general capture costs are lower in EnIIs due the high concentration of CO2 in the flue gas than in the power industry with the exception of the lime industry (Oei, Mendelevitch, & Berlin, 2013; ÖKO, 2012).

The results of an extensive literature review by the IEA (2013) on the capturing costs of a ton of CO2 in different industrial applications can be seen in Figure 1. It can be seen from Figure 1 that capture costs are widely distributed between 10 and 110 USD or 7.5 and 82.5 EUR per ton of mitigated CO2. This leads to the conclusion that it is easier to make CCS economically feasible in some industrial sectors (gas processing, biofuels, aluminum) compared to others (steel, refining).

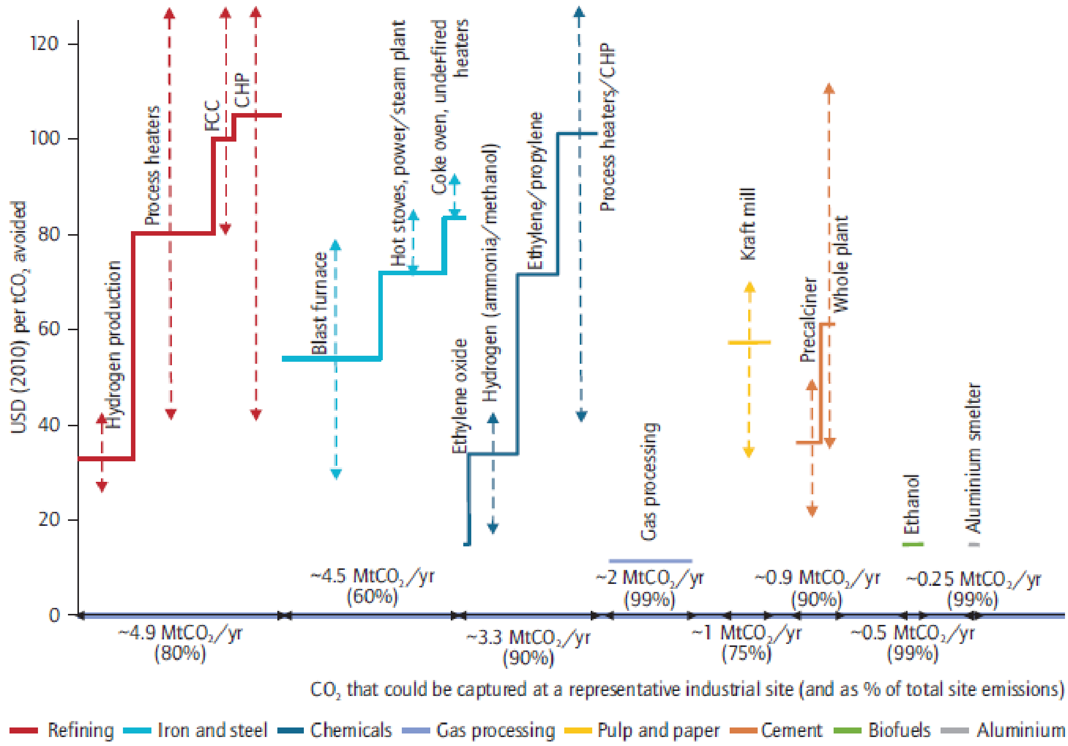

Figure 1: Capture costs estimates per sector (IEA/UNIDO, 2011)

Transport costs

Transport costs are studied less extensively than capture costs due to smaller part of the total CCS costs they represent and the lower technological uncertainties (IEA, 2013b). The costs can be broken down to shipping, onshore pipelines, offshore pipelines and liquefaction (ZEP, 2011). The results of a ZEP study (2011) are presented in Table 2. The shipping costs are confirmed by (Mikunda et al., 2011).

DISTANCE (KM)	180	500	750	1000
ONSHORE PIPELINE (EUR/TON)	1.5	3.7	5.3	na
OFFSHORE PIPELINE (EUR/TON)	3.4	6.0	8.2	16.3

SHIPPING INCLUDING LIQUEFACTION (EUR/TON)	11.1	12.2	13.2	16.1

Table 2: Transport costs (ZEP, 2011)

Storage costs

Storage costs depend mainly on what type of storage is chosen and whether the storage facility is onshore or offshore. The cheapest option is onshore storage in depleted oil and gas fields with a range of 1-7 €/ton CO2 and the most expensive option offshore deep saline aquifers with a cost range 6-20 €/ton CO2. The cheapest storage location are also those that are the least available (IEA/ZEP, 2011).

The costs for the whole chain of CCS are widely dispersed and can be between €10 and €150 per ton dependent on the industrial sector, capture, transport and storage technology and the development of the technology. Costs are lower for some EnIIs than for power.

2.4.3 PROJECTS

The Global CCS Institute (GCCSI) supports a database of all 60 large scale (>800.000 tons of stored CO2 annually for coal-fired power plants and 400.000 tons of stored CO2 annually for other industrial sources) integrated CCS projects globally in all project phases (identification, evaluation, definition, execution or operation) as can be seen in Figure 2. Of all large scale CCS projects only 8 are located within the EU. Of those projects none has reached the execution or the operation phase yet. The number of projects in EnIIs (steel, chemicals and refining) is 11 globally as can be seen in figure 2; only one of those projects is in the EU. The one CCS project in EnIIs within the EU is the Ultra-Low Carbon Dioxide Steelmaking (ULCOS) project in Florange, France. The aim was to install a full chain CCS installation at a steel plant of ArcelorMittal in the North East of France. The company shut down the plants due to the lack of economic viability before the project execution phase started. The other EU projects are in the power generation sector of which Peterhead and Don Valley in the UK and ROAD in the Netherlands seem to be most promising. The GCCSI refers to the situation in Europe as one in which development has stalled (GCCSI, 2014). Reasons for underdevelopment in Europe compared to North America that are mentioned are the lack of potential for Enhanced Oil Recovery (EOR) resulting in a bad business case and high population density hampering infrastructure development (SCCS, 2013a).

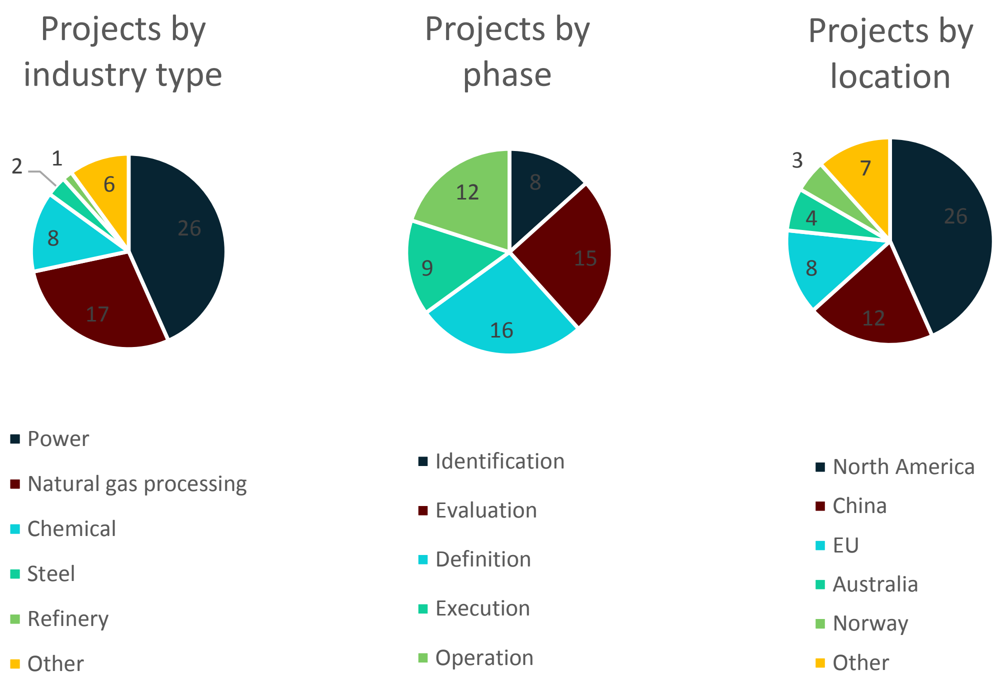

Figure 2: Global CCS projects by industry type, project phase and location[2]

2.3 INSTITUTIONS: BARRIERS

CCS in EnIIs is currently underdeveloped in the EU: there are no CCS projects in operation, while the need for development is evident. Studies have been done to the causes of this underdevelopment identify different institutional causes: economic, social, legal and political. Although these are closely connected, it is a good way to structure this paragraph. The goal in this section is to give an overview of the causes that have been identified in previous studies. The next section goes into proposed and potential ways to overcome these barriers. Stakeholders hold different views on both these barriers and solutions. It will be argued in the next chapter that these different views create the need for including stakeholders' perceptions on barriers and solutions in a process management design.

2.5.1 ECONOMIC

An economic analysis of barriers can be structured by using the concept market failures: if a commodity is not produced by the market but there is a societal need for it, the market exhibits market failures. Often this leads to the conclusion that government intervention is needed. From this perspective CCS is exposed to a number of market failures following from the technological characteristics and state of development of CCS that explain its underdevelopment (Krahé, Heidug, Ward, & Smale, 2013).

[2] http://www.globalccsinstitute.com/projects/browse

Negative externality

First of all, GHGs emitted by industrial point sources can be described as a negative externality: since there is hardly demand for CO2, industries emit CO2 in the atmosphere creating adverse effects for others (i.e. climate change) (Krahé et al., 2013; Von Stechow, Watson, & Praetorius, 2011). The general response to negative externalities is to internalize them, that is, adding the social costs of producing the externality to the producers cost function to incentivize him to produce less of the externality.

Public good

Secondly, the public good nature of knowledge about CCS technology makes that research and development is not directly produced by the market and instruments are needed to incentivize its provision (Krahé et al., 2013; Von Stechow et al., 2011). Firms will only invest in Research & Development (R&D) if they can expect a reasonable return on investment. Investments always have a certain risk, but the returns on investments in production expansion, for example, are at least for the firm itself, while the returns on investments in R&D, knowledge creation, can easily be used by other firms as well. Other firms are not excludable from the knowledge on CCS that firms produce and the competitive advantage of creating knowledge for a firm is reduced (Krahé et al., 2013). Even if all firms would want to create new knowledge, no firm would actually do it. This situation clearly resembles the Volunteer's game in which the worst possible outcome is reached if no one takes action, since the player taking action (and thus producing the public good) will pay for the benefits other players gain.

Imperfect competition

Third, the technical characteristics of an infrastructure system needed for CCS are sensitive for imperfect competition, particularly in the transportation and storage phases of CCS (Krahé et al., 2013). High initial investments and the need for network coordination lead to a small number of firms providing the products. This increases the risk of monopolistic behavior resulting in higher societal costs. Although this market failure mainly arises in later development phases of CCS it has some implications for the earlier development phases. Due to the large investments and the need for coordination there is only a small number of players that can enter this market. If it would be possible for small players as well there would be more risk sharing and possibly more willingness to invest.

Complementary markets

We have already touched upon a fourth market failure, that also has to do with the infrastructural characteristics of CCS: the coordination problem of the design of the transport network and capacity planning (Krahé et al., 2013; Neele et al., 2013; Stephenson, 2013). In a competitive market firms do not try to maximize their joined profit but their individual profit. They will therefore only invest in a pipeline to a storage facility if the total cost of CCS including building the pipeline is lower than the cost of emitting the CO2. But if they would have a neighbor that also faces the same problem they could decide to build a pipeline together lowering the costs for both parties up to 30% by building one pipeline of 36 inch instead of 2 pipelines of 24 inch (Mikunda et al., 2011). This is still understandable when two parties are involved, but gets more complex with more parties. Another issue has to do with timing: firms will adopt the technology at different times. An infrastructure project developer is unlikely to get funding for building overcapacity in its system to take into account the potential need for transport of new CCS adopters (Mikunda et al., 2011). Since we would want the costs of the transport network to be as low as possible this requires complex coordination between all industrial emission sources, storage firms and transport companies due to the complementarity of the markets (Krahé et al., 2013). This economy of scale would also include cooperation between very different industries in EnIIs and power generation (ZEP, 2013a). Herzog (2011) describes CCS transport infrastructure development as a 'chicken-and-egg' problem: CO2 capture will not development without infrastructure, but infrastructure will not develop without capture.

Capital underprovision

The final economic barrier to CCS development is related to the novelty of the technology. Capital needed for CSS projects is underprovided due to the lack of knowledge of CCS technology and risks with financers (Krahé et al., 2013; Sanders, Fuss, & Engelen, 2013; Von Stechow et al., 2011). This issue has to do with the information asymmetry between project developers and financers.

These market failures are strongly interrelated. The occurrence of one barrier reinforces other barriers. The lack of capital provision has a lot to do with the lack of effective policies to tackle the negative externality nature of CO2 emissions and underinvestment in CCS research makes it costs go down less quickly as would be needed to convince capital providers to invest.

2.5.2 SOCIAL

CCS is facing opposition from a social perspective creating development barriers. The most important actors expressing this opposition are local pressure groups and environmental NGOs. Both industries and policy-makers are influenced by this social factor as will be seen from the examples below. Some industries consider lack of public acceptance as a show-stopper (Shackley et al., 2009). When it comes to criticasters of CCS there is an interesting difference between CCS in power and CCS in EnIIs.

NIMBY

CO2 storage projects are typical Not In My Backyard (NIMBY) projects against which opposition of local pressure groups can be expected. An alternative for onshore storage would be offshore storage, but even then the onshore pipelines remain a concern (Shackley et al., 2009). Perceived risks of CCS projects by local residents such as CO2 leakage and earthquakes influence project development whether they are scientifically proven or not (Oltra, Sala, Solà, Di Masso, & Rowe, 2010; Stephenson, 2013). Although most of the public does not know what CCS exactly entails, if it does know it, it considers CCS as slightly positive when put in the context of climate change mitigation, while having a storage location in their vicinity is perceived as negative (Huijts, Midden, & Meijnders, 2007; Shackley et al., 2009). The more fundamental, ethical problem that is behind it can be placed in the scientific discipline of environmental justice: a body of literature on the justice in the distribution of environmental costs and benefits (Hunold & Young, 1998; Ikeme, 2003). CCS transport and storage creates benefits (reduced CO2 emissions) for all people while the costs (risks associated with storage and transport) have to be borne by a limited group of people (Spahn & Taebi, 2009).

An example of how such public opposition can lead to cancellation of a storage project can be found in Barendrecht storage project (Meadowcroft & Langhelle, 2009). Since 2007 there have been plans for an integrated CCS project in the region of Rotterdam. Shell would capture CO2 at one of their refineries near Pernis and store it in a depleted gas field under Barendrecht. What began as critical questions by the local government led to strong opposition of local and provincial governments and local residents (Feenstra, Mikunda, & Brunsting, 2010). Finally, the Dutch national government cancelled the already approved project (Meadowcroft & Langhelle, 2009). Onshore storage is likely to remain difficult, therefore offshore storage is seen as more probable although more expensive.

Consumer prices

A second reason for opposition from the general public are the higher electricity prices due to the application of CCS in power plants (Rochon et al., 2008). If CCS would be applied to power plants and electricity prices would rise because of that, it is likely that the public will be less willing to accept CCS. The willingness to pay for renewable energy is relatively low and it is not expected to be much different for CCS in power (Shackley et al., 2009). Although this concern does not directly works against CCS in EnIIs it still is important. First, the general public does not always discriminate between CCS in power and CCS in EnIIs, therefore a bad image of power CCS will lead to a bad image of EnIIs CCS. Secondly, the same mechanism that increases electricity prices will also be at work for consumer goods prices when CCS is widely deployed in EnIIs.

Competition with renewables

Environmental NGOs have another objection against the development and deployment of CCS: they state that CCS delays the development of non-fossil energy sources. Public funds invested in CCS technology cannot be used in renewables or energy efficiency technologies their argument goes (Meadowcroft & Langhelle, 2009; Rochon et al., 2008). In every emissions reduction scenario there is a need for renewables, also in scenarios with a high level of CCS, so there will always be a need for investments in renewables. However, the level of investments in renewables will be lower when a high CCS scenario will become reality (Shackley et al., 2009). This argument against CCS is only valid for CCS in power. Many NGOs recognize the need for CCS in EnIIs. This leads to a paradox: acknowledgement of the role for CCS in reducing EnIIs emissions implicitly stimulates CCS in fossil fuel power generation. After all, when transport and storage infrastructure and capture technologies for CCS in EnIIs develop, decreasing entry costs for CCS in the power industry. For this reason NGOs takes different positions on the issue: there are proponents and opponents, while some are in favor of CCS in EnIIs, but against CCS in power:

> Bellona: “The Bellona Foundation is very positive to CCS because the organization doesn't believe it is possible to combat global warming without it. Like all environmental NGOs Bellona regards increased energy efficiency and renewable energy as the ultimate solutions to avoid the most dramatic consequences of climate change. However, Bellona is convinced that sufficient reductions of

CO_2 emissions are impossible without all three mechanisms, that is, energy efficiency, renewable energy and CCS [3]."

Greenpeace: "CCS is unproven, risky and expensive and investing in it threatens to undermine the range of clean energy solutions which are available right now [4]."

WWF: "In order to avoid dangerous climate change, there needs to be a rapid decarbonization of the power sector and a radical shift in the way in which the UK and indeed the world sources its energy. Renewables and greater energy efficiency should form the bulk of that shift, but fossil fuels could also play a role, provided they use proven and strongly legislated CCS from the outset [5]."

Friends of the Earth: "Carbon Capture and Storage demonstration schemes should receive incentives and preferably be located on large industrial sites with potential for heat usage and CCS equipped centralized power stations (likely to be cleaner coal rather than gas due to high capture costs from gas power stations) [6]."

E3G: "E3G has taken a positive view on CCS, and they argue for strong and early funding of CCS demonstration plants as critical for delivering climate security. One of their founding directors, Nick Mabey, says that "Climate risks are too high not to take CCS seriously.[7]"

Time dimension

Another objection that is being brought against CCS by Greenpeace is that the technology will not be ready in time (Rochon et al., 2008). Industries will be impeded to deploy CCS due to the lack of technological feasibility until 2030 at its earliest but possibly not until mid-century. That will be too late to deal with climate change, since GHG emissions will have to go down from 2015 on (Rochon et al., 2008).

Increased energy need

According to Greenpeace the reduced energy efficiency of plants also creates threats. The extra energy input for plants equipped with CCS is up to 40% (see section 2.1.2). This would lead to more coal and gas being mined, transported and burned for the same amount of production. It would also require increased usage of scarce water resources (Rochon et al., 2008).

Other social issues

Other issues that are occasionally mentioned by NGOs and the public include the lack of storage space, fear of explosions, damage to marine ecosystems, waste dump to poor countries, not solving the actual problem of CO2

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[3] http://bellona.org/ccs/opinions/ngos.html
[4] http://www.greenpeace.org/international/en/news/features/ccs-not-going-to-save-the-clim/
[5] http://www.wwf.org.uk/search_results.cfm?uNewsID=1764
[6] http://www.foe.co.uk/resource/press_releases/energy_white_paper_reactio_23052007
[7] http://www.e3g.org/index.php/programmes/climate-articles/the-role-of-carbon-capture-and-storage-ccs-in-tackling-climate-change/

emission and reduction of awareness of the problem of CO2 emissions (Oltra et al., 2010; Wong-Parodi, Ray, & Farrell, 2008).

Social opposition against CCS mainly comes from environmental NGOs and local groups organized around potential transport or storage projects. The main concerns are the risks of storage and transport, the costs of CCS and the risk of negative influencing investment in renewables. This opposition is not ignored by industries and policy-makers as can be seen from the Barendrecht example.

2.5.3 LEGAL

Due to the relative novelty of CCS there is no extensive legal framework for CCS while transport and storage of CO2 will have to comply with local, national and international legislation. The main legal issue that has to be overcome is the London protocol that prohibits cross-border storage of CO2. Two issues arise in the capture and transport phases.

Legal issues in infrastructure

When CCS will be deployed on a large scale in the EU a new pipeline infrastructure will have to be developed. Such development requires very extensive Environmental Impact Assessments that would require new legislation (De Coninck et al., 2009; IEA, 2013a; Mace, Hendriks, & Coenraads, 2007). Secondly, as stated before such an infrastructure would be impossible to develop when government allows many firms on the network, there need to be some governmental protection for a monopolistic firm in order to guarantee return on investment. Currently, European law does not provide such protection and allows new players to enter the network freely (De Coninck et al., 2009).

Legal issues in storage

The main issues that arise are in the storage phase. The first one is the cross-border transportation and storage of waste such as CO2. The 1996 London protocol prohibits the export of wastes for dumping or incineration into the sea. Since it is unlikely that all countries will have the possibility to store their own CO2 due to the lack of public acceptance of onshore storage and the landlockedness of some countries there will be a need for cross-border transport of CO2. In 2009 Norway proposed to amend the London protocol to allow for cross-border CO2 transport, however in order to make the resolution come into force two-third of the contracting parties will have to ratify it (Mikunda et al., 2011). The second issue that needs to be addresses is the leakage liability: storage firms need to be liable for CO2 leakage at storage sites, but not for too long periods on time since they will not invest in storage facilities if their risks are too high (De Coninck et al., 2009). Some also point to the need for regulation, but overregulation can have adverse effects for the development of CCS (Radgen, Kutter, & Kruhl, 2009).

2.5.4 POLITICAL

The economic, social and legal issues strongly influence the political arenas. But the political dimension also has other aspects that are not directly related with these barriers. In this section the positioning in the policy field of CCS of the EU will be outlined and national governmental positions will be touched upon. Although, these positions are dependent on economic, social and legal barriers they also can also form barriers themselves in the sense that they create inertia of development.

European Commission

With the adoption of the European Energy Action Plan by the European Commission in 2007 it stated that there is a need for low-emission fossil fuel and industry and therefore a need for more R&D and deployment of CCS in power and EnIIs (De Coninck et al., 2009). In the EU 2030 policy framework for climate and energy it is stated:

> "Greenhouse gas emissions from the EU's energy and carbon-intensive industries must come down significantly to be compatible with the EU's long term GHG objective. As theoretical limits of efficiency are being reached and process-related emissions are unavoidable in some sectors, CCS may be the only option available to reduce direct emission from industrial processes at the large scale needed in the longer term. Increased R&D efforts and commercial demonstration of CCS are, therefore, essential over the next decade so that it can be deployed in the 2030 timeframe. A supportive EU framework will be necessary through continued and strengthened use of auctioning revenues.
>
> In the power sector, CCS could be a key technology for fossil fuel-based generation that can provide both base-load and balancing capacity in an electricity system with increasing shares of variable renewable energy. Member States with fossil reserves and/or high shares of fossil fuels in their energy mix should support CCS through the pre-commercialization stage in order to bring down costs and enable commercial deployment by the middle of the next decade. This must include the development of an adequate CO_2 storage and transport infrastructure that could benefit from EU funding such as the Connecting Europe Facility and any potential successor (EC, 2014)."

National governments

At the EU level CCS is seen as being an essential technology in meeting reduction targets, but in some countries CCS has become highly controversial and therefore national governments are very reluctant. Most notably amongst those are Germany and Poland, while the political climate in Spain, Italy, the Netherlands and The United Kingdom is much more favorable, at least towards offshore CCS projects.

Political volatility

A general CCS project development barrier related to politics is the consistency of politicians and the political time scale (SCCS, 2013a). The political environment is volatile: it depends on elections and is sometimes guided by opportunism. This makes that project developers have difficulty to find financing for their project. Financial institutions expect long term political commitment and stable policy-making before they invest in large scale, long term projects like those related to CCS (SCCS, 2013b).

2.4 INSTITUTIONS: SOLUTIONS AND DRIVERS

Numerous solutions and drivers have been proposed to overcome the developments barriers as described in section 3.2. This section will summarize those policies and drivers that have been identified by literature or reports. These include potential (paragraph 3.3.1) as well implemented policies at the EU level (paragraph 3.3.2) to overcome the economic development barriers and, secondly, drivers for CCS in EnIIs (paragraph 3.3.3) take a broader perspective and also deal with the issue of social and political support. Again, stakeholders have different views on what solution can bring CCS in EnIIs forward. There is no clear best fitting solution leading to the need to design a process in such a way that the different stakeholders perspectives on the solution space is included. This will be elaborated upon in the next chapter.

2.6.1 THEORETICAL ECONOMIC POLICIES ALTERNATIVES

Research to overcome the economic issues has had a strong focus on the power generation industry, following policy priorities. Economic policy studies to incentivizing CCS in energy generation include (Krahé et al., 2013; Lupion & Herzog, 2013; Sanders et al., 2013; Scott, 2013; Torvanger & Meadowcroft, 2011; Von Stechow et al., 2011; Watson, Kern, & Markusson, 2014). The conclusions of these studies are not directly transplantable to CCS in industrial processes due to its very different characteristics: different technologies and costs, lower emissions per emitter and more international competition. CCS in industrial processes has mainly been studied from a technical and capture cost perspective in the steel, cement, petroleum and chemical industry (CONCAWE, 2011; Johansson, Franck, & Berntsson, 2013; Kuramochi, Ramírez, Turkenburg, & Faaij, 2012; Li, Tharakan, Macdonald, & Liang, 2013; van Straelen, Geuzebroek, Goodchild, Protopapas, & Mahony, 2010; Volkart, Bauer, & Boulet, 2013). The International Energy Agency (IEA/UNIDO, 2011) as well as the European Technology Platform on Zero Emission Fossil Fuel Power Plants (ZEP, 2013a) have done extensive studies on CCS in industry with section on policy. So far, no empirical study has been done to what policies will incentive the industry to get involved in CCS. The policies found in this literature will be summarized and they will be valued on their effectiveness to use CCS as a CO2 emission mitigation technology and on their economic efficiency.

Internalizing CO2 emissions

Six main strategies exist for internalizing the CO2 emission negative externality: direct pricing of emissions, the creation of property rights, a hybrid of the two, CO2 purchasing contracts, a feebate scheme and command and control (Krahé et al., 2013). Direct pricing or Pigouvian tax issues a fine upon emitting CO2. Firms will therefore be incentivized to limit the production of CO2 by either developing new technologies or reducing the production of their commodities. Secondly, a carbon tax increases consumer prices of high emission products, thus decreasing its demand and therefore production (Goulder & Parry, 2008). The creation of property rights can be realized by granting firms certain rights to emit CO2 based upon the technology they use and their historic emissions. A maximum economy-wide total level of emissions can herewith be established. By introducing a marketable permit system (cap-and-trade) in which permits can be traded amongst firms the most efficient allocation of permits can be reached. If the marginal cost of reducing emissions of a firm is higher than the price of permits the firm will try to buy permits on the market to minimize its costs and vice versa. Although a cap-and-trade scheme ensures an economy-wide Pareto-optimal outcome its disadvantage is the volatility of carbon prices. The carbon price uncertainty makes investors reluctant on providing funds for CO2 reduction or mitigating projects such as CCS -projects (Krahé et al., 2013; Sanders et al., 2013; Von Stechow et al., 2011). A hybrid version of taxing CO2 emissions and trading rights combines the advantages of both: a long-term decreasing cap on emissions guarantees Pareto-efficiency, while short-term price ceilings decreases carbon price volatility, ensuring investments. This solution, however, demands an independent institution setting price ceilings in a complex environment. CO2 purchasing contracts is a policy that directly incentivizes CCS opposed to the other policies that only promote reduction of CO2 emissions in general. Governmental bodies pay a price for every ton of CO2 captured. Disadvantages are that firms are not stimulated to reduce CO2 emissions, only to mitigate them, and, secondly, that the public resources that are needed are significant. Feebate schemes set an allowed level of emissions for each firm or sector: above this level a fee is to be paid by the firms, under this level firms receive governmental payments (I. Pearson & Whirisky, 2013). The policy requires experienced and professional governmental bodies. Finally, a command and control strategy, such as an emissions performance standard, can be followed in which firms' CO2 production is limited by law (Krahé et al., 2013). This policy should not be seen giving incentives to firms to adjust their production but rather directly controlling the emissions. Command-and-control strategies are generally valued as cost inefficient in reducing emissions.

Overcoming public good

Policy options for overcoming the public good nature of CCS technology include direct public provision of the knowledge (for example via research subsidies or academic research), information exclusion regulation (patents) and assurance contracts. Assurance contracts provide private research funds from beneficiary firms. Another efficient way of promoting CCS technology developments are pricing schemes that guarantee firms return on research investments. Feed-in tariffs (FIT) are well known to have been successful in promoting renewables: long-term costs-based price guarantees are given to firms that develop new technologies such as CCS (Krahé et al., 2013; I. Pearson & Whirisky, 2013; Von Stechow et al., 2011). It is debatable, though, whether FITs will have the same effect for CCS. FITs might give too little certainty for technology development since the return on investment is dependent on energy prices (CCS requires a fair amount of energy), that are volatile. FITs could be adjusted for energy prices creating premium FITs: a standard profit margin for CCS projects. Quantity based portfolio standard, in which a minimum amount of CCS is set, would be another alternative (Menanteau, 2003; Von Stechow et al., 2011). Finally, production, operating or investment tax cuts for CCS projects could also be used to promote technology development although these instruments are a more heavy burden on tax payers (Krahé et al., 2013; Von Stechow et al., 2011).

Introducing competition

The large scale of CCS projects in particularly the transport and storage phases creates a tendency towards monopoly power. Luckily, this is a problem that governments have had to tackle before in for example the electricity production sector in which distribution networks have a monopolistic character. The solution in that sector is a horizontal decoupling between the phases of production, distribution, trade and metering and competition in those phases of electricity generation where competition is possible (Kessides, 2004). The same strategy could be followed for CCS. An assessment of market characteristics (number of potential storage sites, economies of scale, number of firms with knowledge about CCS technology) should be made. If the findings are that the market is potentially monopolistic, CCS infrastructure policy should promote de-mergers and remove barriers to entry (Krahé et al., 2013).

Investor risk mitigation

The lack of funds from private investors in early stages of CCS deployment due to information asymmetries can be overcome by two groups of governmental policies: by providing public funding for CCS projects or to offer risk-mitigation products to private investors (Krahé et al., 2013; Von Stechow et al., 2011).

Complementary markets regulation

Finally, public policies are to be designed that regulate capacity planning needed to coordinate complementary markets in capture, transport and storage (Krahé et al., 2013; Scott, 2013). In the first phase of CCS development, where monopoly power is not yet a big risk, a certain level of vertical integration will have to be accepted in order the balance the capacities and reduce transaction costs (Brunsvold, Jakobsen, Husebye, & Kalinin, 2011). Secondly, public authorities should take the lead in defining what transport and capture facilities are needed based on the amount of capture. The third policy that they should adopt is to provide funding for infrastructure development (Krahé et al., 2013; Neele et al., 2013). When public parties are not involved in infrastructure development societal cost-effectiveness is unlikely to be reached: those industries that can afford to build a pipeline will build it in a point-to-point manner without consideration of the entire system (Chrysostomidis et al., 2009).

2.6.2 EU ECONOMIC POLICIES

After exploring the theoretical policy alternatives this paragraph will describe the economic policies that currently affect CCS in EnIIs.

EU-ETS

The EU Emissions Trading Scheme (EU-ETS) is the mechanism that should provide industries with the incentive to prevent them from producing the negative externality and thus to adopt low carbon technologies such as CCS. The problem with the scheme is twofold. First, the price of emission rights is at present far too low to make CCS feasible: we have seen that the cost of capturing, transporting and storing CO2 is higher than €15 per ton for all industrial sectors, while the value chain price per ton is much higher for most sectors (refining €30-€80, steel €30-75, chemicals €15-€80 and cement €20-€80). The current price of emission rights is around €5,

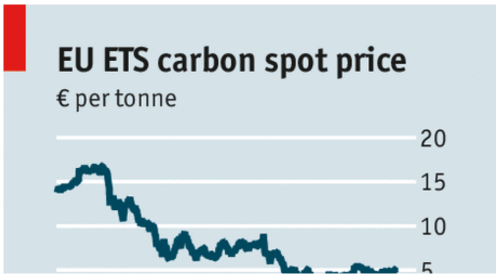

Figure 3: Development of CO2 emission allowances in the EU ETS

making investing in CCS not feasible (Figure 3). But even if the price would go up in the future a second issue remains: many industries are given free allowances in the ETS at not too ambitious levels in order to prevent so called carbon leakage: the replacement of industrial facilities to parts of the world with less restrictive emission policies. Those industries that are very sensitive to international competition including EnIIs such as refining, steel, most chemicals and cement are very vulnerable for further increase of production costs. Including them in the EU-ETS would increase their production costs by either making them pay for extra emission rights or investing in low-carbon technologies. The increased production costs would make them less willing to invest in their production facilities in the EU or even relocate these facilities (Demailly & Quirion, 2006; Dröge et al., 2009). This would have two negative effects: 1) decreased employment in these sectors within the EU and 2) relocating them to part of the world with less restrictive environmental policies could even increase instead of decrease GHG emissions. Border carbon adjustment is often mentioned as a mechanism that could correct for the lower prices of imported products that were produced in a less restrictive carbon regime (Cosbey et al., 2012; Demailly & Quirion, 2006; Dröge et al., 2009; I. Pearson & Whirisky, 2013). We will come back to this in the next paragraph.

Support schemes

As argued before the current economic viability of CCS is limited leading to underinvestment in CCS projects. Since the EU sees CCS as an important technology in combatting GHGs two schedules have been designed to finance CCS demonstration projects and one for CO2 infrastructure development: the New Entrants Reserve 300 (NER300), the European Energy Program for Recovery (EEPR) and the Connecting Europe Facility (CEF).

The NER300 was designed in 2009 to finance commercial-scale CCS and innovative renewables demonstration projects using the funds available from the sale of 300 million EU-ETS allowances. Eligible CCS projects have to fulfill the technical requirements: they comprise the full chain meaning capture, transport and storage; projects in the power sector have to be at least 250MW and in industrial applications at least 500kt/y CO2 has to be stored; and finally, the CO2 capture rate has to be at least 85% (Lupion & Herzog, 2013). Until now the NER300 has not been able to promote CCS due to the decision to not provide funding to CCS projects. First reason is that the amount of financing available decreased from the expected €9 billion to €1.5 billion because of the direct link to the decreasing carbon price. Secondly, the combination of tight specifications for project criteria and major complexity and cost of CCS projects made projects in renewables more attractive (Lupion & Herzog, 2013).

In December 2008 the European Council launched the €200 billion worth European Economic Recovery Plan. It consisted of a series of measures and investments to battle the economic crisis in the EU. Part of the plan was the EEPR with the goal to support the European energy policy objectives amongst which GHGs reduction. Of the €4 billion in the EEPR, €1 billion is specifically for CCS. Although part of this budget has already been paid to CCS project developers, none of these projects has reached its final investment decision (Lupion & Herzog, 2013).

The development of an infrastructure for CO2 transport is one of the essential elements in bringing CCS further (Mikunda et al., 2011). This is even more so the case for EnIIs: since EnIIs are relatively small emitters compared to power plants they will need to share transport and storage infrastructure to realize the minimal scale for economic viability (ZEP, 2013a). It also seems currently unrealistic to expect these kind of investment from market parties (Mikunda et al., 2011). The European Commission has recognized this and has decided to include

CO2 pipeline infrastructure in the Connecting Europe Facility (CEF). The CEF is a €5 billion program for energy infrastructure connection between European countries, such as CO2 infrastructure (EC, 2012).

2.6.3 DRIVERS

In the last two paragraphs we have discussed potential and implemented economic policies to overcome economic issues. In this paragraph we will discuss drivers for CCS in EnIIs industries that can tackle one or several of the economic, social, legal or political issues. These are less clear and broader than the policies mentioned in the other two paragraph since they are highly debated in scientific, business and policy arenas. This paragraph could be seen as a summary of different opinions on how CCS can be brought to a next level.

International climate agreements

Although not many people belief it will happen, ultimately, international climate agreements are a good solution to mitigate climate change and promote low-carbon technologies such as CCS. The EnIIs in the EU are facing heavy international competition from countries that are not included in the EU-ETS or even recognize the Kyoto protocol (De Coninck, Fischer, Newell, & Ueno, 2008). If they would be the only industries in the world that need to battle GHG emissions the mitigation costs cannot be included in the consumer prices (since producers in countries with less stringent environmental policies can offer the products cheaper) and therefore these industries would not be able to produce without making losses. International climate agreement can set emission standards or create an emission trading scheme, creating a level-playing field (IEA/UNIDO, 2011). The possibility of finding international agreement on GHG reduction policies is hard to predict but if we use the Kyoto protocol as the predictor we should not have our expectations too high: the United States and Australia have withdrawn and Canada has largely reneged (De Coninck et al., 2008).

Sectorial agreements

International sectorial agreements are less comprehensive and therefore finding agreement on them is potentially easier (IEA/UNIDO, 2011). These agreements set technology-based performance targets, taxes or best-practice standard for specific industrial processes taking place in multiple countries. Sectorial agreements are not preferred from a macro-economic perspective; an economy wide policy abates emissions in those sectors of the economy were it is the cheapest, therefore a sectorial approach is a second-best outcome in terms of cost-efficiency (Bodansky, 2007). But in terms of actually applying them they have two important advantages over general climate agreements. First, they can broaden country participation since (developing) countries will only have to monitor sectors for which they have the data and capacity and synergies can be created with other policy objectives such as energy security or air quality. The second advantage is that sectorial negations are easier due to the limited number of players: it is easier to identify all actors and easier to find agreement due to the commonality of interests (Bodansky, 2007).

Carbon border adjustment

An alternative for international climate or sectorial agreements that is often mentioned is an CO2 adjustment mechanism: carbon border adjustment (Cosbey et al., 2012). On trade-exposed energy-intensive products that are imported into the EU from countries with no or hardly any GHG reduction policies an extra tax will be levied making those products of comparable price as products produced in the EU under stricter environmental policies. Secondly, exports to those countries from the EU could be subsidized in order to protect EU's exports (Dröge et al., 2009). This policy would only be implemented for those industries that are most sensitive to carbon leakage. In this way EU's industry could be fully included in the ETS (no more free allowances) without inducing carbon leakage. A number of important problems arise here though. First, to determine the value of the taxes and subsidies requires detailed and complex information about productions costs which would be very difficult and costly. The second problem is that carbon border adjustment should be designed in such a way that it is compatible with the World Trade Organization's requirements. Finally, it also poses trade political issues (Dröge et al., 2009).

Creating public support

Most of these economic policies require public funds to be diverted to CCS development and thus not to be spend on something that appeal more to the general public such as education, health care or tax relief. Creating public support for CCS is therefore essential in policy considerations. Promising is that CCS in EnIIs seems to be more acceptable than CCS in power. This is due to the idea that for power production there are alternatives available with renewables (although it seems unlikely that they will develop fast enough to ensure energy supply and we would still need CCS), but for EnIIs there are not really alternatives besides what can be reached with efficiency (IEA/UNIDO, 2011; ZEP, 2013a). Although CCS in EnIIs is more acceptable than CCS in power, still CCS in EnIIs is facing social and political opposition. Furthermore, the problematic public image of CCS in power cannot be ignored since it is strongly connected to that of CCS in EnIIs.

CO2 utilization

One of the solution directions to gain public acceptance that some advocate is CO2 utilization. The use of CO2 in different industrial processes creates demand for CO2 and therefore can improve the business model for CO2 capture and developing a CO2 transportation network (GCCSI, 2011; ZEP, 2013b). Utilization comes in different shapes: first, one should realize that utilization not always means permanent storage; using CO2 can mean that the CO2 is stored in a degrading product and therefore re-emitted after a while. This type of CO2 utilization clearly does not always lead to net emissions reduction. It can lead to a GHG emissions reduction, though, if the CO2 used is a substitute for otherwise produced CO2 (by burning additional natural gas for example). This is the case for the use of CO2 in greenhouses: CO2 can be captured at an industrial point source and transported to greenhouses that use the CO2 for fertilization; although this CO2 will be re-emitted after the products are consumed less natural gas is needed to produce CO2 for fertilization. The same is true for the utilization of CO2 in the production of carbon-neutral fuels such as methanol and methane. These fuels are produced from CO2 and hydrogen and used in transportation or power generation. Although CO2 is re-emitted after combustion there are two advantages of carbon-neutral fuels: they are substitutes for conventional fossil fuels and in that way reduce CO2 emissions and, secondly, they create a solution for the problem of energy storage (R. J. Pearson et al., 2012). The crux is in the production of hydrogen: when this is produced using energy from fossil sources there is a net positive emission of CO2, but when energy from renewable sources is used net emissions are zero (Olah, Goeppert, & Prakash, 2008). The excess supply of solar and wind energy at specific times offers opportunities for energy that can be stored in these carbon-neutral fuels (R. J. Pearson et al., 2012). There are also types of CO2 utilization that do permanently store the CO2 and therefore directly mitigate CO2 emissions. An example of that is mineral storage in which CO2 is used to produce carbonates used in construction. The main challenge is to find a cheap source of metal oxides (ZEP, 2013b).

By far the most advanced and promising way to use CO2 is in Enhanced Oil Recovery (EOR). Oil companies have decades of experience in injecting CO2 in depleted oil field to enhance oil production. Injected CO2 interacts either physically or chemically with the oil that could not have been extracted with conventional technologies (Tzimas, Georgakaki, Cortes, & Peteves, 2005). It has proven to be cost-effective and is practiced on a commercial scale in the US. EOR could become even more interesting with rising oil prices (ZEP, 2013b). One issue that is brought forward by environmental NGOs is that EOR increases the production of oil and in doing so creates CO2 emissions itself and continues to provide unsustainable energy resources (Wong-Parodi et al., 2008). Although not all CO2 utilization technologies lead to CO2 reductions, and even if they do the emissions reduction scale is relatively small, utilization could be used to kick-start CCS due to both the economic viability and the social acceptability (ZEP, 2013b).

BECCS

Another interesting driver could be Bio Energy with CCS (BECCS). Some industrial processes that use biomass as input such as the paper and pulp, power and heat generation and biofuels (substitute natural gas, hydrogen, ethanol produced from biomass) industries could reach negative CO2 emissions over the whole life cycle when equipped with CCS. The trees that are used to produce paper have absorbed CO2 from the atmosphere, in processing the wood to paper part of that CO2 is reemitted, but when equipped with CCS most of the CO2 is captured and stored again leading to negative emissions (Carbo, 2011). BECCS is thus potentially suitable to reduce emissions from sources that are harder to mitigate such as the transport sector. It could provide a more cost-effective way to realize the total GHGs reduction targets. So what makes BECCS a potential driver for CCS? Although social acceptance of BECCS has not been researched directly, research to social acceptance of CCS points out that the prospect of negative emissions can create public support for CCS (Gough & Upham, 2011). Thus, the realization of BECCS projects could induce public support for CCS in general. Secondly, these projects could contribute to create the critical mass needed for economically feasible transport and storage infrastructure. Finally, the CO2 capture costs in Biofuels production facilities is lower than in other sectors, therefore the IEA Industrial CCS Technology Roadmap describes CCS in biofuels as the ‘low hanging fruit’ that could drive CCS as can also be seen from figure 2 (IEA/UNIDO, 2011). The problem with BECCS is that negative emissions are not accounted for in the EU-ETS or any other emission trading scheme, nor is BECCS included in any large-scale CCS demonstration projects. Consequently, there is no financial incentive to invest in BECCS installations at this moment besides the price that is paid for CO2 in industrial usage (Carbo, 2011; Teir et al., 2011).

Energy supply security

since the development of CCS in EnIIs is to a great extent interrelated to the development of CCS in power this analysis of potential drivers should not be limited to CCS in EnIIs: development of CCS in power creates momentum for CCS in EnIIs. One of the important drivers for CCS in power is related to geo-politics: CCS can be understood from an energy security perspective (Meadowcroft & Langhelle, 2009). Reduction of CO2 emissions requires the shift from high emission sources to low emissions sources, on way to do this is shifting from coal to natural gas. Since the gas Europe consumes is produced by a limited number of countries (most notably Russia, Norway and Algeria) there is a strong dependence on these countries endangering supply security. Coal fired-plant plants equipped with CCS can be an alternative that ensures supply security (coal reserves are much more dispersed and abundant than natural gas resources). Thus, CCS can be used as a technology to decrease political dependence on certain countries like Russia, creating momentum for CCS development (Meadowcroft & Langhelle, 2009)

Now all relevant actors technologies and institutions for CCS in EnIIs are described it can be concluded that stakeholders have different interests, are dependent on each other's resources and hold different ideas on what are the barriers and solutions for the development of CCS in EnIIs. Now it is time to turn to a theoretical chapter on how decision-making on issues such as these can be analyzed and organized.

CHAPTER 3: CONCEPTUAL FRAMEWORK

On complex issues such as CCS in EnII, decision-making (the phenomenon studied in this thesis) is not straightforward. This chapter goes into the theory of decision-making. Several concepts and models will be explained and consequently the choice of process management as the guiding model of this study will be defended. This chapter ends with a description of the pitfalls of process management and how it could be improved. It concludes that by enriching the process managerial approach with stakeholder frames, decision-making can be improved both from an instrumental and normative point of view. This serves as the starting point for the empirical exploration of stakeholder frames on CCS in EnIIs in the succeeding chapters.

3.1 CONCEPTS IN DECISION-MAKING

Problems and solutions

Decision-making is about problems and solutions. It is about what solution to choose for what problem. The starting point for decision-making can therefore be that someone perceives a problem. So, what is a problem? A problem is often conceptualized as a gap between an existing or expected situation and a desired situation (Haan & Heer, 2012). Some also point to the coupling between problems and solutions, no problem without solution, therefore to speak of a problem two conditions need to be met: 1) There is a gap between an existing or expected situation and a desired situation and 2) There is a dilemma: there is an expectation that something can be done about the gap, but it is not readily apparent how best to proceed (Enserink et al., 2010).

There are different ways to typify problems, but useful for our purpose is to think about problems in two dimensions: knowledge uncertainty and agreement on norms. This typology can be seen in Table 3.

	CERTAINTY ABOUT KNOWLEDGE	LITTLE CERTAINTY ABOUT KNOWLEDGE
CONSENSUS ON NORMATIVE STANDARDS	Tamed problems	(Un-)tamable scientific problems
LITTLE CONSENSUS ON NORMATIVE STANDARDS	(Un-)tamable ethical problems	Untamed political problems

Table 3: Typology of problems (Douglas & Wildavsky, 1983)

By far the easiest problems to solve are those with agreement on norms and certainty about knowledge. Harder to solve would be when there is little certainty about knowledge, this is typically an engineering problem: everyone agrees that is a need to do something and engineers have to find out what. When there is little uncertainty about knowledge but disagreement on norms we have an ethical problem. By far the hardest problems to solve are those where there is no technical and no normative agreement: untamed problems. Where Douglas and Wildavsky (1983) use untamed problems to describe these type of problems, others use unstructured (H. De Bruijn & Heuvelhof, 2002) or wicked (Rittel & Webber, 1973) problems. CCS in EnII clearly resembles this type of problem: agreement on normative standards is lacking and there is great knowledge uncertainty. As we have seen in chapter 2 actors have different and sometimes contradictory interests: industrial production and emissions reduction are directly coupled and actors value the importance of both activities different. There is no agreement on what role the different stakeholders should play and who should pay. Who is responsible to move first? Normative standard are thus lacking. Secondly, actors do not agree on knowledge. Does CCS create environmental risks? One actor would agree, the other disagree. Is CCS technology 'ready'? It depends on what actors think ready means. And why is CCS development stalling? Is it the economics or is it the socio-political context? There is little certainty about knowledge in CCS in EnIIs, making it an untamed political problem according to this typology. This is important, since it will be part of the argumentation used in the next section.

Actors, resources, interests and frames

let us turn from the objects of decision-making, problems and solutions, to the subjects of decision-making: actors. Actors could be defined as "persons, organizations or groups that are capable of making decisions in a more or less coordinated way (Hermans, 2005, p. 14)." Alternatively, more pointing to the characteristics of actors they could be described as "those parties that have a certain interest in the system and/or that have some ability to influence that system, either directly or indirectly (Enserink et al., 2010, p. 80)." Actors and stakeholders are often used interchangeable and that convention will be followed in this study, but some point at a difference between the two: the concept of stakeholders is sometimes used for actors that have interests in decision-making, but limited means to influence it (Enserink et al., 2010).

The second definition already points to two of three key characteristics of actors: interests, resources and frames. Actors have interests that are strongly related to concepts such as objectives, values, preferences or positions. Although some of those are of a more abstract level, all of them describe directions in which the actors would like to move and are related to the internal motivation of actors (Enserink et al., 2010). Secondly, actors have resources, means or instruments: practical tools to reach their objectives. Examples of resources include money, knowledge, relations and authority. As can be understood from these examples resources are closely related to power: the ability to make other actor move in the desired direction or prevent from moving in the undesired direction (Hermans, 2005). Finally, actors see the world through frames, also described as perspectives or belief systems. Frames comprise the set of ideas that actors have about how the world around them functions, both of other actors and of the substantive characteristics of problems. It is important to realize that although interests and frames and related they are fundamentally different: frames are theories of how the world operates that the actors holds, while interests, values or objectives tell us how an actor desires the world to operate (Enserink et al., 2010). A further exploration of this difference will be made in the last paragraph of this chapter.

3.2 MODELS OF DECISION-MAKING

Phases

Historically the first perspective on policy analysis was developed by Harold Lasswell just after the second world war and describes policy as a cycle of several discrete stages or phases. Although he formulated it as a normative model and it is widely used as ideal type of rational decision-making it could also serve as an explanatory model.

The model describes policy making as a process of analysis of the best policy option to fit with the policy problem (Jann & Wegrich, 2007). At least policy formation, policy adoption and policy implementation are recognized as distinct phases in the cycle, while others add agenda-setting and evaluation at respectively the beginning and the end of the cycle (Jann & Wegrich, 2007; Teisman, 2000).

Streams

A second group of models of decision-making is the result of critiques on the discrete phases of the former model: policy problems do not only occur at the start of the policy process nor do solutions only appear as response to problems. The role of the policy maker also changes in these models (Jann & Wegrich, 2007). One of these models describes decision-making a garbage can model in which four streams will have to come together in a certain configuration and each with a certain magnitude for a decision to be taken: a choices stream, a problems stream, a solutions stream and a stream of energy from participants. This model views decision-making as a situation in which preferences are problematic, technology unclear and participation fluid. Decision-making is thus not rational since it depends strongly on the availability and interaction of the streams instead of the decision-maker's preferences (Cohen, March, & Olsen, 1972). Building upon this idea Kingdon (1984) develops a model consisting of three partially independent streams: a problems stream, a solutions stream and a parties stream. Solutions float around looking for problems and for political opportunities to increase the likelihood of being adopted. The coupling of the three stream can be seen as a window of opportunity, this is the moment a decision is taken. A policy entrepreneur makes use of the coupling of solutions and problems and invests available resources to get certain gains (Kingdon & Thurber, 1984).

Advocacy coalitions

Sabatier and Jenkins-Smith (1993) consider coalitions of actors with shared ideas on policy issues as the main element of analysis. Actors within a coalitions share beliefs systems, advocate problems and solutions and often act jointly. Coalitions are in competition with each other, but conflict can be mediated by another group of actors: policy brokers whose concern is to find a compromise between different coalitions (Hermans, 2005). The result of policy-making should thus be seen as the result of a competitive system of coalitions. Two types of variables also play a role in determining the constraints of decision-making: stable (such as resource distribution and institutional context) and dynamic (such as decisions taken on other policy fields, socio-economic context and public opinion). These variables may cause that a coalition changes its beliefs. The last element that plays a key role in the advocacy coalition framework is policy oriented learning. Sabatier and Jenkins-Smith state that certain factors may facilitate learning across coalitions that lead to changes in belief systems (Hermans, 2005).

Arguments

The argumentative decision-making model could be summarized in Habermas' claim that 'different people hold different truths, that none of these individual truths has more value than others, and that people can only attain agreement on truth by means of argument, i.e. by exchanging their views on what they belief to be true (Hermans, 2005).' The argumentative models focus on the process of argumentation: on the arguments and on the style of argumentation (Fischer & Gottweis, 2012; Forester, 1993). This argumentative process is believed to lead to a common truth that can serve as the starting point for decision-making (Hermans, 2005).

Games

As the name suggest game decision-making models are based on game theoretic concepts such as players, games and arenas. Actors' or players' behavior can be explained as rational decision-making in a game. Actors weigh the benefits and losses they obtain from choosing a certain action and that determines the outcome of decision-making (Hermans, 2005). Although game theory suggest rational decision-making, many scholars apply Simon's concept of bounded rationality (due to limited cognitive capacities or information asymmetries) to these models (Hermans, 2005; Simon, 1991).

One of those models is Teisman's rounds model. Teisman (2000) states that decision-making does not take place at a single moment in time, but should be seen as a combination of different rounds of decisions. The game that is played in the next round is determined by the outcome of the former round. It considers strategic behavior as a key part of the policy process: different actors participate in different rounds and they are not necessarily in the same phase of the process. Some might consider the round one of implementation while other act as if they are in the phase of policy formation. In different rounds those actors will participate which possess the needed means or resources or have an interest in that particular round. The presence and behavior of actors is thus to a large extent determined by strategic motives (Teisman, 2000).

Networks

Network models focus on the network of actors as the main element of study. Network characteristics such as number of actors in the network, interactions between actors and distribution of power within the network serve as explanatory variables for the outcome of decision-making. Networks consist of actors, relations and institutions (Hermans, 2005). In network models power and interests are key concepts. Actors are interdependent because they need each other's resources, but they often has (partially) contradictory interests:

> "Due to specialization, professionalization, decentralization, individualization and informatization there is an increasing number of places in society where people, groups and organizations make decisions. As a result there is increasing fragmentation. Simultaneously, these local decision-maker have limited resources and are influenced by the decision of others. The mutual decency between local and central parties increases. Horizontal relationships are formed: networks (Koppenjan & Klijn, 2004, p. 3)."

Network models have been used as the starting point for developing network management strategies such as network management (Kickert, Klijn, & Koppenjan, 1997) and process management (De Bruijn, Ten Heuvelhof, & In 't Veld, 2012).

3.3 CHOICE OF MODEL: NETWORK DECISION-MAKING

Clearly, none of the above mentioned models is wrong or right; all of them have some truth. Which model is the right one is therefore the wrong question. A better question would be: which is the most suitable one for our objective to improve decision-making on CCS in EnIIs? We believe the network model can be of most use for a decision-making process such as that on CCS in EnII for three reasons:

1) it fits well with the empirical situation of CCS in EnII.

One of the criteria of choosing models to describe reality is whether the models 'fits' with reality. Elements that are important in reality should be reflected in the model. CCS in EnIIs can be characterized as a network of actors that are highly dependent on each other. None of the actors can do CCS alone. It is highly unlikely that CCS in EnII will move forward without support of the industry who has to implement it, with research institutions that co-create the technology, with government for regulation and financial support or with NGOs for social acceptance and political pressure. The actors need each other's resources. Simultaneously, the actors have contradictory interests: they all want the others to pay for CCS. These two characteristics: resource interdependency and diverging interests are central in the network model as well.

2) It offers practical tools for improvement of decision-making.

When choosing a model the objective should not be forgotten: to give recommendations on improving decision-making on CCS in EnII. The aim is to not only conduct an academic exercise but to come up with practical advice. The network model is not just an analytical tool, but has, as mentioned before, lead to practical guidelines on how to manage networks and therefore on how to improve decision-making. Other models are less well developed when it comes to practical recommendations.

3) It is a relevant academic debate.

Network decision-making and the management recommendations deriving from it are still relatively new (1980s and 1990s) and debated (Hermans, 2005). Moreover, there is currently no reason to think that models that describe interdependencies between actors and diverging interest will lose their value soon. On the contrary, global issues such as climate, energy, population growth and so on might demand more insights in network decision-making.

3.4 MANAGING NETWORK DECISION-MAKING: PROCESS MANAGEMENT

When we consider decision-making to take place in a network, De Bruijn et al. (2012) argue, we need a process approach. In a process approach the focus of management changes from the content to the process itself. Secondly, in a process approach parties will have to agree on how decision-making takes place before going into the content. And finally, the agreements will have to guarantee that parties have to opportunity to serve their own interests. So why do we need a process approach in network decision-making?

A network needs a process, De Bruijn et al. (2012) continue, because of 6 reasons:

1) Reduction of information uncertainty

For unstructured or untamed problems it is of great importance to have all relevant information available. Often different parties have acces to different information. The confrontation between different sources of information can improve the quality of the information. Therefore, all relevant parties have to be involved in decision-making.

2) Enrichement of problem definitions and solutions

Different parties often have different (normative) perceptions of problems and solutions. A confrontation between these differences can enriche decision-making. Moreover, it can also enriche an individual party's perceptions: having knowledge of other perspectives can improve one's understanding of the issue and lead to a different valuation of the other party's perception.

3) Incorporate dynamics

When involving all relevant parties one ensures that the dyamics of constantly changing problem definitions and solution directions is incorporated in the decision-making process. New information can lead to different conclusions. This gives the oppurtunity to parties that want to frustrate the process to reject the decision by arguing that new information proves the taken decision is not the right one. This can be prevented by ensuring that the new information is available within the process by involving all relevant parties.

4) Transparancy

Decision-making processes are often extraordinary disordered: many parties, many procedures, and many issues. A process-design leads to some transparency on where we are in the decision-making process and what decisions have been taken.

5) Depolitising

A strong content focus can lead to strong opposition. When taking a process approach, not being clear what the final outcome will be only about the way it will be organized, this opposition can be toned down.

6) Support

Some parties have blocking power, meaning that when is decision is taken that is not to their liking, they have the ability to stop the execution of the taken decision. To prevent this from happening all parties that have such power should be included in the decision-making.

3.5 PROCESS DESIGN

So now it has been argued that a process approach can lead to better decision-making in a network environment, we should think about how to design such a process. We have already touched upon some of those criteria implicitly (such as involving all relevant parties), but we need a more systematic exploration. According to De Bruijn et al. (2012) a good process design fulfills 4 criteria or core elements:

I) Open

Openness of the process has two dimensions: it is about who participates and about what is on the agenda. So how to determine the parties that should participate? First of all, parties that have significant production or blocking power should be included in the process. Secondly, the parties that are invited to participate should be representative for the parties that have an interest in the decision-making. Meaning that all interests are represented without inviting all parties. These two mechanisms lead to the conclusion that it is important to make an analysis of the resources and interests that parties have. Consequently, one should consider that different phases of the process might require different parties to be involved. Finally, there could be reasons (from a moral point of view) to include parties that do not have significant power. The commonly used focus on power and interests can be visualized in a 2-dimensional power/interest matrix as can be seen in Table 4. Such a matrix is frequently used in deciding who to involve.

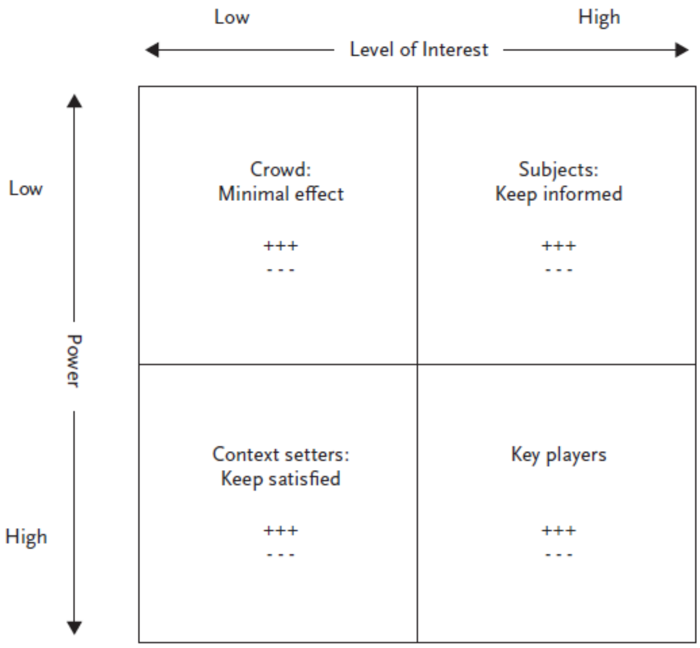

Table 4: Power/interest matrix (Bryson, 2004)

Now about the agenda: it should be clear at the beginning that the agenda is open. Therefore, no decision should be taken about the content a priori, rather, one should make agreements on how to come to decisions: process agreements. In addition to that, these process agreements should be transparent to create trust. At the beginning of the process the number of issues on the agenda should thus not be limited: a multi-issues agenda should be created. Although this might create more complexity it can ease decision-making because of the following mechanism: party A might need party B for issue 1, party B needs party C for issue 2 and party C needs party A for issue 3, this interdependency creates the opportunity the take a decision about the three issues while there would have been a potential stalemate if only one issue was addressed. In the case of CCS in EnII this triangle can well be illustrated: industries need policy-makers and politicians to make support policies, policy-makers and politicians need NGOs to find public support for these policies and NGOs need industries to implement emission reduction technologies. When putting all of these issues on the agenda (support policies, social acceptance and emissions reduction) there are better opportunities to reach decisions than when only one issue is addressed.

There potentially occurs an issue in such a process design: it might be very hard to include parties that are not willing to participate. What we typically see in the case of CCS in EnII (following from chapter two) is that there is a group of actors that is reluctant to participate: some environmental NGOs. They have a strong negative attitude towards CCS and do not see it as part of a solution, participating in decision-making on CCS would acknowledge its potential as a solution. A good process should also represent this interest. How can this be done according to De Bruijn et al. (2012)? Their answer is that the process should do the work: first some of the process' participants that have relations with the reluctant actors could inform them every now and then or ask for some advice. Gradually, they will be approached by more and more different parties and start to feel they should be part of the process.

II) Protection of core values

Openness has the risk of making the process unattractive for certain stakeholders. The risk for participating parties is that the outcome at the end of the process (when withdrawing from the process is not so easy) is against their interests. Therefore, a process design needs to protect the core values of participating parties. Parties cannot be forced to act against their *raison d'etre.* Related to this, parties cannot be asked to be committed to the results prior to the process. The same is true for partial decisions: committing oneself to partial decisions can feed the feeling of a trap or 'point of no return'. At the end of the process parties will be asked if they are committed to the full package of decision: nothing has been decided until everything has been decided. Finally, there should be exit rules: exit rules lower the barrier to enter a process.

Of course actors are tempted to bring all of their viewpoint forward as core values, but they will learn that when all actors do this it will create an unworkable process. Actors have the opportunity to see a number of core values protected but it will not be accepted to have too many 'core values'.

When looking at the actors in CCS in EnII what core values should be protected to incentivize participation? It all depends on what the actors themselves consider their core values. For the industries this might be to not give information on confidential company numbers. For politicians democratic representation is one of the core values, they therefore cannot be asked to agree to a decision before they have had a mandate from whom they represent. Whatever these core values are, it is ultimately the actor itself that decides on what its core value is. In designing a process these core values will therefore have to be formulated by actors and made into process agreements.

III) Progress

the combination of an open process with the protection of the party's core values can lead to endless debate and negotiation. Therefore, a good process design includes mechanisms that guarantee a certain amount of progress. One of the mechanisms that could be used is to build in a prospect of profit, this could be done by designing a multi-issue agenda. Secondly, 'quick wins' should be possible, for example by putting an non-controversial topic on the agenda. Progress could also be guaranteed by engaging senior representatives from the parties: senior representatives increase the external authority, the commitment of the party and they are often capable of taking a helicopter view. The organization of conflict could be essential as well. Often processes have steering groups, project groups and working groups. Conflict should be organized in the lowest groups as to protect people in the decision-making layer, the steering group. Sometimes, a process creates momentum for the application of command and control. When parties see for example that decision-making is to slow, they can be willing to accept a certain degree of hierarchical decision-making. The incentives for progress are summarized in Table 5.

COOPERATIVE BEHAVIOR

Several mechanisms are available to create cooperative behavior.

AGENDA WITH PRODUCTION POWER

The multi-issue agenda has to be designed in such a way that each of the actors has the opportunity to use its production power. Production power is used to create something and therefore lead to progress.

PLANNING OF ACTIVITIES

The planning of activities has to be done intelligent, either sequential or parallel. When party A wants quick decision-making, while party B wants careful decision-making sequential decision-making creates incentives for progress. The first step could be a quick scan of alternatives before going deeper into one of them. This first step will be fast, but is has to be acceptable for B, so it should be done careful enough so as for B to accept the study and not demand a new one. Parallel planning of activities is better when different interests of different parties are served with the activities. Doing them at the same time makes parties to find a compromise for both activities.

THIRD PARTY INTERVENTION

Inviting a third party in case of a conflict between groups of actors can help creating new room for negotiations. Third parties can reframe the issues or multi-dimensionalize it. Reframing tries to formulate a research question (and an answer to it) that can solve the conflict. Multi-dimensionalizing comes down to reformulating the issue from a dichotomous into an issue with more than two viewpoints.

REPETITIVE OPPORTUNITIES FOR GAINS

Decision-making on a specific issues should not occur only once; parties should have to opportunity to ask for reconsidering the outcome of a research or reinvestigating alternatives. This might seem to slow the process down, but for parties with large interests in a process they need some guarantee that they have the opportunity the rethink the decision to take the decision.

SENIOR REPRESENTATION

High level representation of the parties should be realized in a good process. High level representatives have large networks that create cooperative behavior. Secondly, a senior representative has more space to negotiate, they are responsible for a broader package.

QUICK WINS

In the beginning of a process it is often still very fragile. Relation are relatively new and trust between parties with contradictory interests is limited. In such a context it might not be wise to start talks about controversial topics. Still, there is a need to make progress: process management should ensure quick wins about non-controversial issues.

CONFLICTS DEEP IN THE PROCESS

A process should be designed in layers. In the top layer, the steering group for example, there should not be too many conflicts to keep the process going. Therefore conflict should be organized in the lowest possible layers of the process (working groups). Preferably even outside the process. The positive effects created by the conflict outside or in the lower layers of the process (better information, explicit viewpoints) can be used in the steering group to reach decisions. In this way the positive effects of conflict can be combined with the negative (bad relations) since the people in the steering groups are not damaged by the conflict. If it is impossible to organize conflict on a low level one should at least ensure that within the steering group there are changing coalitions. Block formation can be dangerous for the process.

COMMAND AND CONTROL

Sometimes a process offers, in specific situations opportunities for command and control strategies. Command and control can potentially boost cooperation in a decision-making process. Say two parties are in a negotiation, but one of the parties has the ability the unilaterally impose a decision upon the other, the other has a good incentive to find agreement.

Table 5: Incentives for progress in process management (De Bruijn et al., 2012)

IV) Quality of the content

Finally, the first tree elements could have a tendency towards poor quality decisions. The content of decision could be meaningless or even wrong. It is therefore important to involve content experts in the process. They can serve as a mechanism to control the quality of the taken decisions. The second way quality could be improved is to move from variety to selection. At the start of a process all alternatives should be considered to keep all parties on board, but also to improve the quality. Later in the process a selection of alternatives should be created based on shared insights.

3.6 PITFALLS IN PROCESS MANAGEMENT

De Bruijn et al. (2012) describe a number or risks or pitfalls of process management. A process could be perceived as a way of communicating an already taken decision instead of a decision-making process. It could be seen as a means to explain what has been decided, while in fact nothing has been decided; clearly, this will frustrate the process. Secondly, what is often presented as a process is in practice a project with extensive stakeholder involvement. The decision-making will have a clear goal, defined boundaries, a limited budget and constrained time. These are all elements that do not characterize a process, but still are communicated as such. A third pitfall is that process management can lead to slow decision-making. Finally, decision-making can lead to poor decisions due to fact that agreement has to be found among many stakeholders.

There is more to say about the pitfalls of process management. Let us first critically review the used argumentation. De Bruijn et al. (2012) mention six reasons why in networks process management is the desired strategy, according to them it can reduce information uncertainty, enrich problem definitions and solutions, incorporate dynamics, guarantee transparency, depoliticize and create support. Indeed, these issues should be addressed in a network decision-making environment. Consequently, they state that four core elements should be realized in order to guarantee a good process: openness, protection of core values, progress and quality of the content. Does such a process design fully serve the six mentioned reasons to opt for process management?

It could be argued that this is not fully the case. Or at least not in the way De Bruijn et al. (2012) use them. Their main focus in selecting who should be part of the process is on power and interests. They argue that those with production or blocking power should be included and that all interests should be represented. Why will this not be enough to serve the six reasons?

The first reason they mention, information uncertainty, will be decreased with such an approach, but uncertainty about what type of information? Information on content knowledge will be decreased and information on the different interests and resources will be decreased as well. But there is no guarantee that information on the different views on the issue that live in society is included in the process. Selecting participants based on power or interests could lead to a process where certain frames are not represented and thus not considered. Lacking knowledge on such crucial information could lead to problems when implementing the taken decision.

The second reason, enrichment of problem definitions and solutions: surely the proposed process design can lead to enrichment of problem definitions and solutions. But the understanding of the problems and solutions could be further enrichment by including more world views or frames in the process. Enriching the decision-making with more frames can increase the quality of the decisions taken because they are based on a more comprehensive understanding of social reality.

The sixth reason they mention, support, could be improved by incorporating different frames in the decision-making process. When stakeholders realize their ideas were not considered in the decision-making process they will be more reluctant to support the decision that has been taken. The conclusion here should be that there are ways to improve the process design in order to better guarantee at least three of the six reasons process management should be applied: information uncertainty, enrichments of problem definitions and solutions and support.

But there is another reason why the process design could be improved that is not related to those six reasons. For this discussion it might be useful to introduce three rationales for inclusive stakeholder participation: instrumental, substantive and normative (Ciupuliga & Cuppen, 2013). These same rationales can also be applied to process management. The instrumental rationale points to stakeholder participation as a means towards a particular end. In the case of CCS in EnIIs it would mean to include local residents in the process in order to create support for a storage project. The substantive rationale refers to improving the quality of the decision-making by including stakeholders: this relates to what De Bruijn et al. (2012) call 'enrichment of problem definitions and solutions'. The normative rationale constitutes a more fundamental argument: stakeholders should be involved because it is their political, democratic or moral right.

In process management the focus is on the instrumental and substantive rationales for participation as can be seen from the six reasons to practice process management (De Bruijn et al., 2012). It is worth questioning how well process management serves the substantive rationale though; as argued before more enrichment of problem definitions and solutions could be better guaranteed by including different perspectives. Secondly, process management hardly considers the normative rationale. It is not fair to say that they forget about the normative rationale at all since they state that in selecting the process' participants one should also take into account that some stakeholders need protection and should therefore have a role in the process, but what about the stakeholders that do not need protection (De Bruijn et al., 2012)? Including them just for gaining support or improving decisions is not enough and will not work without a third message: decision-making has to be inclusive from a democratic perspective. Will people truly feel part of the process when they are in it because they have the needed resources, they represent certain interests or they need protection? "In order to make participation "work", it should thus not be framed only in instrumental terms "to create acceptance" but have strong grounding in substantive and democratic notions, allowing for a dialogue between project developers and/or policy makers and stakeholders (publics) (Ciupuliga & Cuppen, 2013, p. 226; Fiorino, 1990) ". It is doubtful whether process management, with is pragmatic focus, can convince stakeholders that their views are incorporated in decision-making. Including frames in a process design can provide legitimacy because it gives stakeholders the message that their view is considered in the decision-making process.

A last argument that can be made against the proposed process design is that there are opportunities for creating a more deliberative process. Although De Bruijn et al. (2012) do mention that an actor dialogue can lead to better quality information and more understanding of the problem at hand, it should be clear that when interests and values are contradictory it is hard to find agreement on information or problem definitions. Drawing on a variety of public deliberation and social learning literature, Schusler, Decker, and Pfeffer (2003, p. 311) define social learning as "learning that occurs when people engage one another, sharing diverse perspectives and experiences to develop a common framework of understanding and basis for joint action". Therefore, true learning takes place through insight in each other's perspectives or frames. When stakeholders understand where viewpoints or values stem from, from what world view they are derived, it is easier to learn from each other. Within the process management approach this element seems underrepresented.

3.7 THEORETICAL CONTRIBUTION: INCLUDING FRAMES IN PROCESS MANAGEMENT

In the last section five issues in the process management approach were outlined: information uncertainty on stakeholders' world views can lead to implementation problems, problem definitions and solution space should be further enriched, public support can be too limited, process management lacks a democratic rationale and limited social learning or deliberation.

The cause of these shortcomings can be found in the first core element: openness. Openness is described as an open agenda and open participation. But its operationalization using resources and interests does not reflect this openness well enough: an inclusion of frames in selecting the process' participants could improve the process design.

CCS in EnIIs can be understood as an untamed political problem in which consensus about both knowledge and norms is lacking (see section 3.1). Hisschemöller and Hoppe (1995) argue that in the case of ill-structured or untamed political problems a strategy could be to include actors with different views on the problem. The interaction between people with different perspectives on the problem can lead to the emergence of new insights (Cuppen, 2012; Hisschemöller, 2005; Webler, 1995).

An argument that could be made with a strong face validity against including frames in a process design is that it practically does not add much because frames and interests are two sides of the same coin. Therefore, including interests in a process design indirectly guarantees inclusion of frames. One should realize, though, that frames significantly differ from interests. Frames are ideas on how the world works, while interests have to do with what an actor wants the world to be like. An actor's normative beliefs are related to its beliefs on how the system functions, but it is easy to imagine that actors holding similar frames come up with very different objectives. Similarly, the same objectives could stem from very different frames.

Empirically, we can also show that interests and frames do not always go hand in hand. De Bruijn et al. (2012) state that a way to ensure all interests are represented in the process a stakeholder selection can be made based on affiliations (organization type for example). But a stakeholder selection based on affiliations can give a very different outcome compared to selection based on frames as is shown for the Biomass debate in the Netherlands (Cuppen, Breukers, Hisschemöller, & Bergsma, 2010). That interests or affiliations and frames can greatly differ could also be illustrated by the Zero Emission Platform example. Two NGOs are represented in the platform that are in favor of CCS, while other NGOs that are strongly against CCS are not represented. The same organizational type with ultimately shared interests (limiting CO2 emissions) have very different ideas about the role this

technology can play in reducing emissions and about the problems that can occur when deploying the technology (for more on this see section 4.2.2). Selections based on affiliation or interests here does not guarantee inclusion of world views or frames. While NGOs are represented in the platform, and NGOs share their interests with other NGOs, they could have different frames on CCS, and they do in practice.
Note that when introducing the concept of frames in process management we also return to some of the decision-making models introduced in section 2.2.2. We have already mentioned Sabatier's belief systems, but frames also reflect the argumentative models and Habermas' claim that 'people can only find agreement by exchanging their views on what they belief to be true (Hermans, 2005, p. 11)'.

Process management enriched with stakeholder frames is suitable for designing and managing decision-making on CCS in EnIIs. Before turning to the practical implications of this, first there is a need to explore the stakeholder frames. The methodology to research stakeholders' frames is described in the next chapter.

CHAPTER 4: METHODOLOGY

This chapter will describe the research methodology used to answer the third research question: *What frames can be identified that stakeholders use to understand CCS in EnIIs?* The methodology used for that is Q methodology. First, it will be argued why Q is suitable and consequently, the methodology will be explained and applied.

4.1 CHOICE OF METHODOLOGY

One of the main contributions of this study is the development of frames in which stakeholders think about CCS in EnIIs. What is meant by those frames has been elaborated upon in Chapter 2, what methodology can be used to find frames will be outlined in this section. As stated in that chapter the frames that are the subjects of study here are not ways individuals see social reality, but views that are shared by a group of actors. A methodology that is particularly suitable for this goal is Q methodology. Q methodology can group individual frames into social or shared frames (Barry & Proops, 1999).

Q methodology was developed by physicist and psychologist William Stephensen in 1935 as a means to extract subjective opinion in psychology. It has been practiced outside the discipline of psychology in fields such as communication and political science (Cross, 2005). More recently it has been applied in many other disciplines for measuring perspectives on issues including health and the environment (Steven R. Brown, 1996; Cross, 2005). Durning (1999) suggests that Q methodology should be used in policy analysis more often to bridge the gap between positivist traditional policy analysis and post-positivist theory that takes a more subjective epistemological position. Post-positivists reject the possibility to separate fact from value, for them meaning is multiple and constructed. Q methodology can take that into account since it tries to identify the way actors view the world: the frames they use to think about CCS in EnIIs (Durning, 1999).

Why is the method so well in finding frames for CCS in EnIIs? First of all Q methodology is a qualitative approach with statistical elements. Q methodology leaves more space for respondent’s input than what is called R methodology: the traditional statistical approaches such as surveys pre-define the elements that respondents have to use to construct their view (Dryzek & Berejikian, 1993). Q is different in two ways: the elements that are used in q (statements) are coming from the research population themselves and, secondly, the interpretation of the statistical analysis strongly depends on the qualitative input of the respondents. Q has the potential to uncover unanticipated attitudes (Addams & Proops, 2000). In finding frames it is valuable that Q combines open, explorative qualitative with the robust statistical scientific research elements. The second reason way Q methodology is suitable to find frames is that it is especially well-suited to deal with subjective issues that are “socially contested, argued about and debated” (Addams & Proops, 2000; Durning, 1999; Stainton Rogers, 1995). Frames on CCS in EnIIs are such issues as can been concluded from Chapter 1. Finally, Q methodology asks respondents to compare statements rather than rate them (Cuppen et al., 2010). It can be argued that comparing statements in such a way is closer to how people construct social reality (their individual frame) than rating individual statements and therefore Q can give a more accurate description of how respondents view the issue than R methodology can do.

Q methodology is interested in establishing patterns within and across individuals rather than patterns across individual traits (Barry & Proops, 1999). Q methodology does not lead to conclusions on the population of actors but on the population of frames (Van Exel & de Graaf, 2005).

4.2 Q PROCEDURE

There is no general agreement on the number of steps Q methodology comprises, but around four (Durning, 1999), five (Van Exel & de Graaf, 2005), six (Barry & Proops, 1999; Cuppen et al., 2010; Watts & Stenner, 2005) or seven (Webler, Danielson, & Tuler, 2009) steps are mentioned most frequently. Although, this number can differ somewhat, the scope of activities that have to be executed to perform a q based study is generally comparable. In this study six steps will be used:

1) concourse definition
2) selecting the Q set
3) selecting the P sample
4) Q sort
5) statistical analysis
6) interpretation

4.2.1 CONCOURSE DEFINITION

The first step in the Q procedure is to identify the concourse (Van Exel & de Graaf, 2005). The concourse can be defined as the “the flow of communicability surrounding any topic in the ordinary conversation, commentary, and discourse of everyday life (Steven R. Brown, 1993).” It thus comprises the complete set of subjective statements, objects, images etc. that can be made or shown about the issue under study (Van Exel & de Graaf, 2005). In this study we are looking for the attitudes of stakeholders in the CSS in EnIIs arena towards barriers, drivers, problem definitions and solutions spaces that comprise what has been defined as a frame. The concourse is therefore limited to verbal statements on problem definitions, solutions, barriers and drivers about CCS in EnIIs.

The concourse can be collected from many different sources such as (without striving for completeness) interviews with experts and stakeholders, scientific articles, reports and newspaper articles (Van Exel & de Graaf, 2005). In this study statements have been derived from 12 semi-structured phone interviews with experts on CCS, reports of ZEP (2013a), the GCCSI (2014), UNIDO and the IEA (2011) and SCCS (2013a, 2013b), and scientific articles and books on CCS. The interviewees were representatives of companies involved in CCS from the power industry, NGOs and research organizations. The full list of interviewees can be found in appendix 1. They were asked what they think of the interest of the EnIIs industries in CCS, what barriers they see for development and what could move the EnIIs towards CCS.

4.2.2 SELECTING THE Q SET

From the concourse the Q set has to be derived: the set of statements that represent all dimensions of the concourse and tries to capture its complexity. The Q set has to represent all the ideas that live in the concourse and is therefore also called a Q sample in some studies. The number of statements a Q set contains depends on the study: too few statements lead to a bad representation of the full concourse which results in respondents not being able to express their frames by doing the Q sort, while too many statement results in Q sorts that are too time-consuming for respondents. Typically, the Q set can contain up to 60 statements, while less than 20 is generally considered too few (Van Exel & de Graaf, 2005; Webler et al., 2009).

The Q set in this study was compiled by selecting, after categorization, the unique statements from each category. Empirical categories were iteratively created according to our own judgment of what statements were about similar topics. The number of statements per category can be found in Table 6. Occasionally, statements were combined or rephrased into new statements. The list of selected statements can be found in appendix 2.

Category	# Statements
Emissions reduction and the role of CCS therein	6
Environmental risks	12
Technological development	3
Cost	10
Financial incentives	13
International competiteveness & policy	12
Utilization	11
BECCS	3
Social acceptance	10
Political acceptance	6
Legal compliance	2
Transport infrastructure	5
Economic barriers	5
Employment and the role of EnIIs in the EU	6
Relation with CCS in power	7
Knowledge and attitude of EnIIs about CCS	3
Demonstration & Pilot projects	2

Table 6: Categorization of statements

From the 117 statements that constituted the concourse 47 statements were included in the Q set by selecting the unique statements from each category. It is likely that other researchers would have selected a different set in a different way, but it is important to realize that this does not create problems within q methodology: first, although another researcher may a arrive at a different Q set, both sets can be representative for the concourse and, secondly, it is the subject, the respondent that gives meaning to the Q set by sorting the elements (Van Exel

& de Graaf, 2005). For Q methodology, inter-researcher validity seems to be high (Thomas & Baas, 1992).

Using the set of 47 statement test-interviews were conducted with three experts in the field of CCS in EnII. From the tests three conclusions were drawn and the Q set and interview procedure were changed accordingly. First, the number of statements was concluded to be too large and the Q sort therefore too time consuming to properly do the Q sort. The risk of losing the respondent interest due to the set size was mitigated by decreasing the Q set to 31 statements. Secondly, for some of the statements it was very hard to oversee all the consequences or too complicated due to the technical nature. Some of these statements were left out and some reformulated into more general statements. Finally, one of the test respondents wanted to be more free in the sorting, it was therefore decided that respondents were allowed to make a more free sort when they requested it. Brown (1980) concludes that the effects of the choice of distribution (i.e. free or forced) are practically irrelevant.

4.2.3 SELECTING THE P SET

After selecting the Q set, the P sample has to be selected: the group of stakeholders that will be asked to give meaning to the Q sample by doing the Q sort. Compared to R methodology, in Q methodology the requirements for the number of respondents are much lower. The selected respondents are not selected randomly, though, they are purposively selected since they exhibit certain characteristics. The P-sample should not be an opportunity sample, but should be based on a coherent rationale (Watts & Stenner, 2005). First, they need to have an important connection with the issue at hand. Secondly, they also need to be knowledgeable and have a distinct, well-established view on the matter (Van Exel & de Graaf, 2005; Webler et al., 2009).

Let us recap the goal of this Q methodology study: finding the frames that stakeholders use to think about the issue. The P sample therefore needs to contain all these different frames amongst them. Therefore, theoretically the minimum number of respondents needed is rather low, in practice, more respondents increase the chance of being complete, i.e. finding all frames. The number of frames can range from 2 to more than 5 and we will need a couple of participants per frame, so at the upper end with 5 frames and 3 respondents per frame we will need about 15 respondents. On the other hand the ratio between observations (Q statements) and variables (Q sorts) should not be much lower than 2:1 or order to find statistically significant results. Therefore, with 31 statements we should not have much more than 15 respondents (Webler et al., 2009). The number of respondents should thus be around 15.

Practically, many potential respondents were approached from a list that was available at the ZEP secretariat. Some of these people were representatives of EnIIs companies. They were all specialist in the area of CCS within their company which was needed for the needed knowledge level of CCS to sort the statements was relatively high. These respondents were from different industrial sectors (steel, chemicals, cement and refineries). Two respondents were from environmental NGOs and three from the European Commission. One respondent was affiliated with the a research institution and one member of the European Parliament. The full P sample of 14 people can be found in appendix 3. Many more were approached to take part in an interview, but many did not reply or had a negative reply often pointing at their lack of knowledge, time or involvement of their organization in CCS.

4.2.4 Q SORT

The Q sort is the step in which respondents give meaning to the data. The respondents from the P sample are asked to rank the 31 statements in the Q set. The condition of instruction was to rank the statements according to what extent the respondent agrees with the statements: 'Please rank these 31 statements from most disagree on the left side to most agree on the right side'. The ranking was forced into an approximate normal distribution by asking respondents to place the statements that were written on cards on fixed squares as can be seen in Figure 4.

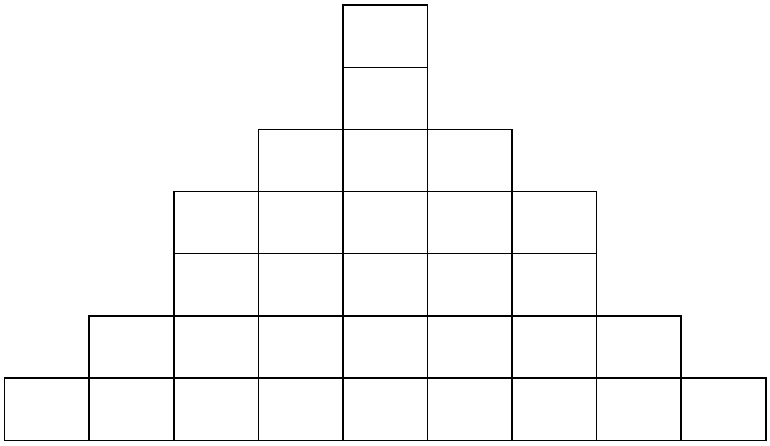

Figure 4: Q sort distribution

As Watts & Stenner point out: "the distribution is a relative non-issue from your perspective; as long as you use some kind of standardized distribution, your participants' viewpoints will be captured appropriately (2005, p. 77)." From the participants' perspective the steepness of the distribution does matter: they need to feel comfortable with the sort they have made. In this study it is decided that the steepness should be relatively large. In this way there are fewer statements that respondents are forced to place at the extremes, making them feel more comfortable with the their distribution of statements. This is especially suitable for issues on which respondents either are no experts on or that are controversial (Watts & Stenner, 2005). CCS in EnIIs is highly controversial as can be understood from Chapter 2 and it is not unlikely that some of the respondents do not have elaborate knowledge of the matter since their organization is not dedicated to CCS. To make to Q sort easier for the respondents it was suggested to first make three piles of statements with increasing rate of agreement before further ranking the statements within the piles. Finally, respondents could decide to not put all the statements in the forced distribution. Although this might make respondents feel more at ease with their sort, the drawback is that it could actually make the sort more complex and time-consuming for them while not increasing the information that can be gathered from it (Watts & Stenner, 2005). Three respondent took that opportunity, but only with one or two statements.

During and after the Q sort open questions were asked that helped in interpreting the frames. Especially the reason for ranking certain statements at the extremes can contribute to understanding the frames (Steven R. Brown, 1996; Cuppen et al., 2010; Van Exel & de Graaf, 2005). After the interview respondents were asked whether they had thought about how CCS in EnIIs could be brought further. And finally, they were asked whether they missed any statements. Most respondents were satisfied with the Q set and others mentioned an issue that was already included in the Q set. Two issues that were mentioned that were excluded from the Q set when reducing the number of statements from 47 to 31 were international sectorial agreements and political volatility. Both issues were addressed in two other statements but only in a very general way. The interviews lasted between 60 and 120 minutes.

4.2.5 STATISTICAL ANALYSIS

The fifth step, the statistical analysis, is in theory a purely technical-mathematical one in which interpretation does not play a role (Van Exel & de Graaf, 2005). Q methodology is based on factor analysis: a statistical method to find clusters of elements; in the case of Q methodology those elements are the Q sorts. The clusters of Q sorts that are found form the factors that have to be interpreted in the final step to define frames. In practice, though, the process of analysis and interpretation is iterative: to determine the number of factors that should be extracted from the data an objective statistical analysis does not always provide the best solution. It might provide a mathematically optimal solution, but it does not guarantee the best solution in the sense that it gives the most meaning to the data (Watts & Stenner, 2005). Secondly, the statistical analysis does not necessarily give a single answer and therefore still requires the judgment of the researcher. This judgment can be based on theory and interpretation of the data. A sound analysis results in a solution that is " a) sensitive and responsive to your data set and thus to the feelings and viewpoints of your participants; b) satisfactory in relation to your own aims and purposes; c) methodologically and statistically, as well as theoretically, acceptable; and d) makes good sense of the data you have gathered (Watts & Stenner, 2005, p. 96)." For now we will focus on the strictly statistical part, turning to the interpretative part in the next step, but we should keep in mind that in practice this process is not as strictly separated as is suggested here.

The availability of software for the analysis greatly reduces the amount of work in the statistical analysis, but the procedure will have to be well understood in order to critically interpret the results. Therefore, a description of the statistical procedure will be provided here.

First, scores are attributed to the distribution starting at -4 at the most left column up to 4 at the most right column. Pearson's correlation coefficient is calculated for each pair of Q sorts leading to the correlation matrix. This matrix contains a large richness of information. In order to make sense of the information we will try to summarize the data in a way that makes it easier to interpret. This is what factor analysis can do and the technique is therefore a data reduction technique. From the correlation matrix, a factor is extracted based on the similarity between Q sorts (Van Exel & de Graaf, 2005). For each of the Q sort the correlation with this first factor, or factor loading, is calculated; this number tells us how typical the individual Q sort is for factor 1 (Watts & Stenner, 2005). A new correlation matrix, the table of first residuals, is calculated by subtracting the product of the factor loadings of the Q sorts on factor 1 from each of the cells of the original correlation matrix. The table of first residuals forms the starting point for the extraction of a second factor and so on. For each Q sort the communality can be calculated by summing up the squares of the factor loadings. The communality of a Q sort is the fraction of the variance in a Q sort that has been accounted for in the factors. Similarly, for each factor the squares of the factor loadings can be added up constructing the eigenvalue of the factor. The common variance that a factor accounts for can be calculated by dividing the eigenvalue by N the number of Q sorts (Watts &

Stenner, 2005).

The factor extraction can be done using either principal component analysis (PCA) or centroid factor analysis (CFA). These is general agreement amongst Q methodologists that CFA provides the best alternative for Q. PCA is a mathematical transformation that gives one mathematically best solution, no matter the interpretation of these factors. This may result in factors that have no meaning in social reality. In Q research we want to combine statistics with our interpretation of it and theory, CFA leaves space for that (Watts & Stenner, 2005). So far we have purposively neglected one important decision: when do we stop extracting factors from our correlation matrix? There is no clear-cut answer to that question, but Q methodologists have developed several criteria or aids that can be used to determine the number of factors that should be extracted. These criteria can be found in Table 7.

KAISER-GUTTMAN CRITERION	TWO SIGNIFICANT Q SORTS
Those factors that have an eigenvalue larger than 1.00 should be included.	Those factors that have at least two Q sorts with significant factor loadings should be included.
MAGIC NUMBER SEVEN	**HUMPHREY'S RULE**
The number of factors that should be included is around seven, based on experience.	Those factors for which the (absolute value of the) cross-product of the two highest factor loadings is larger than twice the standard error should be included.
PARALLEL ANALYSIS	**SCREE TEST**
A factor should be included if there is less than 5% chance that the observed eigenvalue could have been found in random data.	The number of factors that should be included is indicated by the point where the slope of the eigenvalue curve changes.

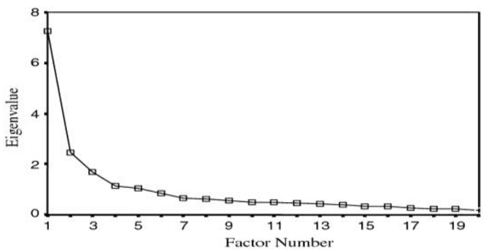

Table 7: Criteria for choosing the number of factors in Q methodology (Watts & Stenner, 2005)

After the factor extraction another technique can be applied to make more sense of the data. Say, a number of factors, N_F, have been extracted using CFA and the criteria. These N_F factors constitute a N_F-dimensional Hilbert space, meaning that they can be seen as a system of N_F perpendicular axes (although this is hard to visualize for

$N_F > 3$). The Q-sorts have a score on each of these dimensions or axes: their factor loading for each of the factors. It might very well be that two groups of Q sorts have an average score on two of the factors. This makes it hard to determine the meaning of these factors. What we could do is rotating the two axes such that the two groups of sorts have a high score on one factor and a low score on the other factor as can be seen in Figure 5 (Watts & Stenner, 2005). This eases the interpretation and makes the interpretation of the factors more meaningful.

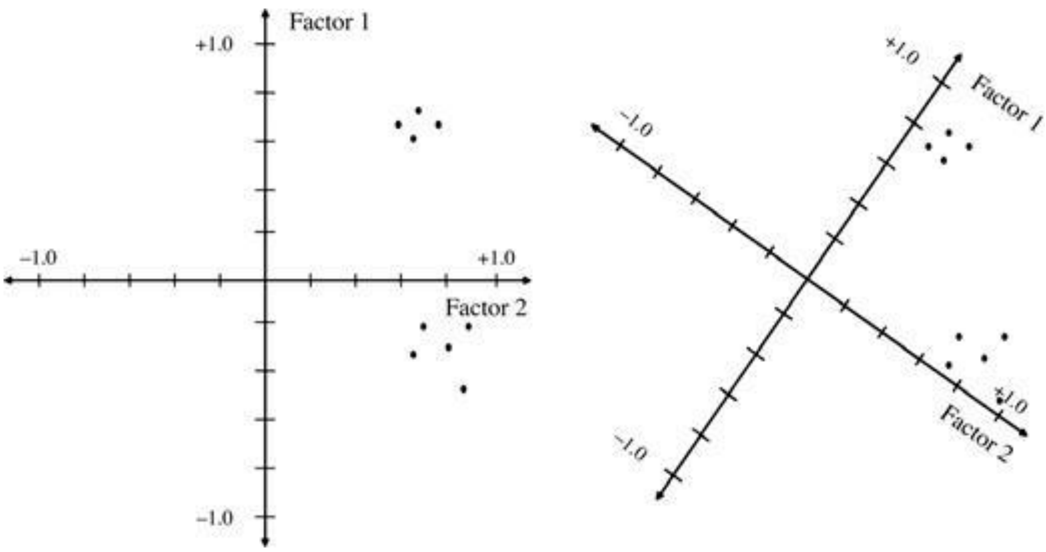

Figure 5: Illustration of factor rotation (Watts & Stenner, 2005)

In the example in Figure 5 the axes have been rotated in such a way that they are still perpendicular: they constitute an orthogonal space. Although, sometimes oblique rotation is applied in factor analysis in which there is no necessity to keep the angle between the axes at 90^{o}, in Q, orthogonal rotation is the standard. The methods exist for rotation: by-hand rotation and varimax. Varimax statistically determine the rotation that maximizes the explained variance without consideration on meaning of those factors. When rotating by-hand the researcher can influence the rotation based on theory or expectation. It is therefore less inductive than varimax. A combination of the two can be used complementary (Watts & Stenner, 2005).

Having identified the factors, now we can identify the Q sorts that typify the factors. Q methodologists often use the Q sorts that have a statistically significant factors loadings on those factors. For each of the statement a Z-score can be calculated for in relation to each of the factors. Finally, a factor array can be created based on these Z-scores which exemplifies the factor by ranking statement in a Q distributions (Watts & Stenner, 2005).

In this study the rotation was done by-hand and iteratively. First, a seemingly best fitting rotation was made of the factors that were selected. Consequently, an attempt was done to interpret those. Then a new rotation was done and a new attempt to interpret. This procedure was repeated a few times. Finally, four factors were included. Partially, the criterion was followed that at least two Q sort seed to have a significant loading on a factor; for one factor there was only one significant loading. This factor was still included in the study since it entails an interesting and well-interpretable frame.

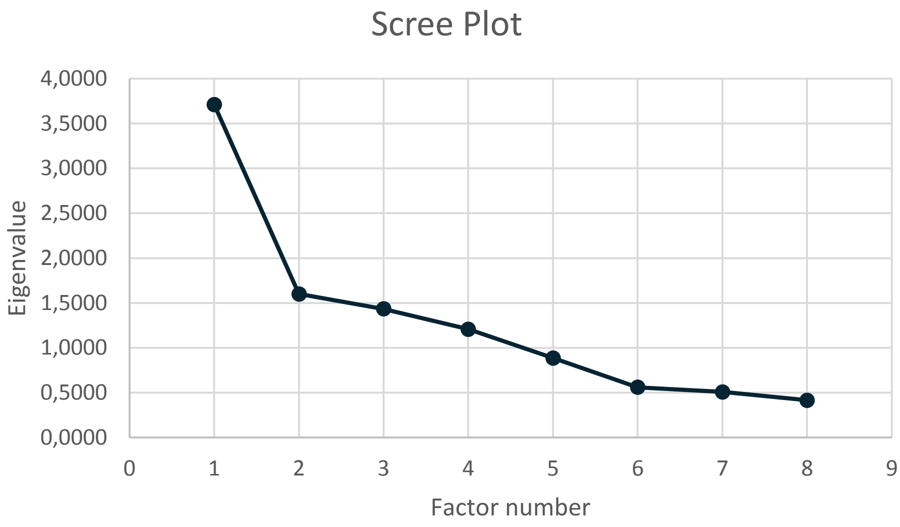

Figure 6: Scree plot

Using the scree plot in Figure 6, 5 or 6 factors could have been used as well, but this did not give interpretable factors, and secondly, the number of Q sorts per factor was too limited.

4.2.6 INTERPRETATION

As mentioned before the statistical analysis is full of interpretative elements and these last two steps should therefore be seen as an iterative process. The interpretation of factors can be guided by different sources of information: the Q sorts with high and significant factors loadings on those factors, the statements at the upper or lower extreme of the factor array (also called characterizing statement), and thirdly, the explanation respondents gave for ranking statements in the way they did (Van Exel & de Graaf, 2005). It helps to understand the frames in relation to the other frames: the differences and similarities between the factor loadings and explanations for the different factors (Cross, 2005). All these elements were used in this study and a further explanation of the factor interpretation can be found in the next chapter.

CHAPTER 5: RESULTS

Now it has been argued that decision-making on CCS in EnIIs can benefit from a process management approach enriched with stakeholder frames and the methodology has been described to find these frames, in this chapter the results of this methodology will be described.

5.1 FRAMES: FACTOR INTERPRETATION

Four frames have been found that stakeholders use to view the world of CCS in EnIIs. They include problem definitions and solution directions. All frames recognize the importance of economics in this issue. They either consider international competition one of the main barriers or that there is no fitting economic incentive for the industry to develop and deploy CCS. It gets more interesting, though, when looking at what is behind or next to this economic view. Four different frames have been identified.

FRAME 1: IT’S THE SUFFERING INDUSTRY, STUPID!

This perspective strongly emphasizes that the EU’s industry is in a very difficult position. It is already suffering and the future for the industry in Europe is not very promising. Reduction of the industry’s emission will lead to even more problems for the EnIIs. The most important statements in this perspective are statement 18: Because EnIIs are facing international competition, emissions reduction is very difficult for them and 13: CCS in EnIIs will make consumer prices unacceptability high. Although these statement are the strongest in this perspective, most perspectives recognize international competition as a key issue, therefore there are statements that differentiate more between this frame and the others. The important statements are summarized in Table 8.

Clearly, these statements also point out that it is not the unwillingness or short term orientation of the industry why CCS in EnIIs is underdeveloped but it is the difficult economic position they are in. Their position is more difficult than the one of the power industry, that is not suffering from international competition, therefore CCS in power is easier than in EnIIs. The power industry and the EnIIs often have conflicting interests. Respondent 6 point out that some of the EnIIs (cement and steel) already have to deal with constantly decreasing demand in Europe, which is not likely to change. When CCS is applied to the EnIIs, consumers will not accept the increase in price. Noteworthy is also that two environmental arguments against CCS are being brought forward as important as well. The objective could be strategic: saying that environmental concerns are important as well gives legitimacy to this perspective.

The suggested way to a solution is that governments provide the financial resources needed for CCS. There is no way the industry can do CCS without financial support from public parties.

MOST AGREE	18: Because EnIIs are facing international competition, emissions reduction is very difficult for them. 9: New CCS demonstration projects in EnIIs should be one of the main priorities. 13: CCS in EnIIs will make consumer prices unacceptably high.
MOST DISAGREE	25: Instead of CCS we should drastically decrease our production.

	22: The lower capture costs in EnIIs compared to the power industry creates opportunities for early development of CCS in EnIIs. 5: EnIIs are not investing in CCS because of their short term orientation.
OTHER DISTINGUISHING STATEMENTS (AGREE)	15: The deployment of CCS in EnIIs creates unacceptable environmental risks. 21: CCS should not be part of an emissions reduction strategy, since it increases the use of fossil fuels.
OTHER DISTINGUISHING STATEMENTS (DISAGREE)	29: The EnIIs and the power industry have many common interests when it comes to CCS and should work together. 31: Carbon border adjustment should be implemented in order to prevent carbon leakage.
INTERVIEW QUOTES	*"Currently, the EnIIs just have extra costs for abating emissions. We need more carrots than sticks. The awareness of the state the industry is in Europe is not good. Everybody wants to protect the environment and climate, but the consequences of that for the industry are not fully assessed (respondent 10)."* *"I would like to see more cooperation with the US, China and OECD countries on the policy-making level. If we try as Europe to solve the problem alone, it does not work (respondent 10)."*

Table 8: Most significant statements and quotes for frame 1. In the row 'most agree' and 'most disagree', the statement that was ranked highest or lowest, respectively, is the first statements in the row.

FRAME 2: IT'S THE LACK OF COOPERATION, STUPID!

This perspective is rather optimistic about the opportunities for deploying CCS in EnIIs. The perspective agrees most to statement 1: 'CCS in EnIIs in indispensable in meeting EU's emission reduction targets' and disagrees most with statement 13: 'CCS in EnIIs will make consumer prices unacceptably high'. The cost of CCS for cement will only marginally increase the costs of a house (respondent 6). Consumers will hardly notice the increase of price due to CCS in refining in the fuel prices (respondent 1). Table 9 summarizes the most important data for frame 2.

International competition is recognized as a key issue for CCS in EnIIs, at the same time this perspective point the EnIIs themselves: their short-term orientation makes that they do not invest in CCS. Also other actors should take their responsibility: NGOs should be clearer in their choice for CCS. Industry-wide cooperation can also support the development of CCS and, very important, demonstration plants should be built.

Respondent 1 points to the importance of cooperation between the industry and policy-makers. The costs of the technology is known by the industry, but not by the policy-makers. Therefore the policy-makers cannot design the right policy incentives. Closing the loop, this makes that the industry does not invest in CCS. When the EnIIs and the industry participate in an open decision-making process, meaning they are open about the information they have, policies can be designed that can stimulate the EnIIs to do CCS. At the same time these policies should not create carbon leakage. This can only be prevented by open decision-making. This does not only go for the costs of CCS but also for carbon leakage. The information asymmetry between EnIIs and EU policy-makers on carbon leakage makes that the European Commission cannot implement the needed policies. NGOs and the power industry also have to be part of this decision-making. Policy-makers and EnIIs should go into an open dialogue. Industries know what the costs of CCS is, policy-makers have limited knowledge and can therefore not find the right policy-mechanisms. In an open dialogue the industry should give information, so the right policies can be designed.

MOST AGREE	1: CCS in EnIIs is indispensable in meeting EU's emission reduction targets 9: New CCS demonstration projects in EnIIs should be one of the main priorities. 18: Because EnIIs are facing international competition, emissions reduction is very difficult for them
MOST DISAGREE	13: CCS in EnIIs will make consumer prices unacceptably high. 11: CCS decreases the general awareness of the problem of CO2 emissions. 25: Instead of CCS we should drastically decrease our production.
OTHER DISTINGUISHING STATEMENTS (AGREE)	23: It would help if more environmental NGOs would be in favor of CCS in EnIIs. 5: EnIIs are not investing in CCS because of their short term orientation. 29: The EnIIs and the power industry have many common interest when it comes to CCS and should work together. 8: The European Commission has to be more outspoken in favor of CCS in EnIIs.
OTHER DISTINGUISHING STATEMENTS (DISAGREE)	22: The lower capture costs in EnIIs compared to the power industry creates opportunities for early development of CCS in EnIIs. 13: CCS in EnIIs will make consumer prices unacceptably high.
INTERVIEW QUOTES	*"The European Commission is the only organization that can formulate a long term vision, it is therefore very important that they are positively outspoken about CCS. The European Commission should be leading (respondent 2)."* *"The EnIIs do not have all the knowledge about infrastructure and storage; another stakeholder should help them. Governments have to play a role there. We need a dialogue to build trust between policy-makers and the industry. The industry will need to understand that policy-makers will not force CCS upon them, but want to look together how to realize CCS. Policy-makers have to show that they take initiative to develop infrastructure (respondent 2)."*

	"The industry is very good at complaining that it is all going to become more expensive, but we do not know the costs until they are transparent about it. We need an open process that can give us the right information (respondent 1)." *"More knowledge sharing is important between stakeholders (respondent 14)."*

Table 9: Most significant statements and quotes for frame 2. In the row 'most agree' and 'most disagree', the statement that was ranked highest or lowest, respectively, is the first statements in the row.

FRAME 3: IT'S THE POLICY, STUPID!

This perspective, for which the statements used for the interpretation can be found in Table 10, emphasizes that CCS in EnIIs should be understood in terms of policy. The two most important statements are both about the mechanisms that should currently incentivize the deployment of CCS. In this frame international competition is not seen as one of the main barriers. It is more about finding the right policy that will create the right environment for CCS: it is a technocratic approach in that sense.

MOST AGREE	10: The low price of allowances in the EU ETS is one of the main barriers for the development of CCS. 1: CCS in EnIIs in indispensable in meeting EU's emission reduction targets. 16: The uncertainty in ETS allowance prices is one of the key barriers to CCS development.
MOST DISAGREE	7: Technology for CCS will not be ready in time to mitigate climate change. 11: CCS decreases the general awareness of the problem of CO2 emissions. 25: Instead of CCS in EnIIs we should drastically decrease our production.
OTHER DISTINGUISHING STATEMENTS (AGREE)	
OTHER DISTINGUISHING STATEMENTS (DISAGREE)	18: Because EnIIs are facing international competition emission reduction is very difficult for them. 30: CCS will contribute significantly to maintaining employment in the EU's EnIIs.
INTERVIEW QUOTES	*"In the end it is not about what the NGOs or industries want; if governments want something they can make it happen. If governments would be really in favor of CCS it would happen. It is the degree of commitment that governments bring to the table. If the commission would be able to show that the right policies for CCS can be developed, any party will be in favor (respondent 9)."*

	"The policy incentives to get there are various, so we should not lay it on all the ETS (respondent 9)." *"The free allowances in the ETS due to the carbon leakage lists are currently not being distributed in the right way. The commission knows that the list is a fiction, if you would sell some more allowances you could invest that money in de-carbonization technologies such as CCS (respondent 9)".* *"Governments should produce a clear roadmap, otherwise industries will lean back and wait. Industries are willing to abate emissions but they need a clear and reliable policy (respondent 11)."* *"I am in favor of carbon border adjustment, of course it has to meet WTO (world trade organization) rules and it is difficult to govern, but it is essential in a policy framework that incentives CCS. Secondly, if Europe would state they were to introduce something like this, it would help moving the global climate agenda. Countries will respond to the idea because they will lose potential markets in Europe (respondent 13)."* *"If we get a new commissioner that is dedicated to CCS and start making policy, that is what can drive the development (respondent 7)."*

Table 10: Most significant statements and quotes for frame 3. In the row 'most agree' and 'most disagree', the statement that was ranked highest or lowest, respectively, is the first statements in the row.

FRAME 4: IT'S THE WHOLE PACKAGE, STUPID!

The last perspective is the one where public acceptance comes in. It recognizes the importance of most other elements: international competition, the policy framework and the need for stakeholder cooperation, but it is the only frame in which social acceptance attracts attention as well. Characterizing statements are found in Table 11. International competition and the ETS allowance prices are considered important together with social resistance. It is not that people will not accept the increase in prices due to CCS, but more the technology in general. Therefore decision-making on CCS in EnII cannot be continued without considering public acceptance. International competition is considered a key barrier for emissions reduction, but when public acceptance can be realized the right policies can be designed to incentivize CCS in EnIIs and international competition could be battled in that way. It should be noted here that even in this frame social acceptance is not among the most important issues, still the other issues are considered more important, therefore this frame is called: It's the whole package, stupid! In this frame all the different issues are seen as being dependent on each other, CCS in EnIIs cannot be brought further when one of these elements is neglected.

MOST AGREE	10: The low price of allowances in the EU ETS is one of the main barriers for the development of CCS in EnIIs. 18: Because EnIIs are facing international competition, emissions reduction is very difficult for them.

	29: The EnIIs and the power industry have many common interest when it comes to CCS and should work together.
MOST DISAGREE	7: Technology for CCS will not be ready in time to mitigate climate change. 3: EnIIs have a moral obligation to invest in low-carbon technologies such as CCS. 15: The deployment of CCS creates unacceptable environmental risks.
OTHER DISTINGUISHING STATEMENTS (AGREE)	28: Public resistance is one of the main problems with CCS.
OTHER DISTINGUISHING STATEMENTS (DISAGREE)	
INTERVIEW QUOTES	*"We need national governments to support CCS projects, otherwise they will not happen. For that social acceptance is the main barrier (respondent 12)."* *"For sure social acceptance is important. That is typically what you see for all technologies such as CCS, because they are Not In My Backyard projects (respondent 8)"*

Table 11: Most significant statements and quotes for frame 4. In the row 'most agree' and 'most disagree', the statement that was ranked highest or lowest, respectively, is the first statements in the row.

5.2 COMPARISON OF FRAMES

In Table 12 the four frames are compared using a number of issues that appeared to be important in one or several frames. The table makes clear how the frames relate to each other. The plusses and minuses indicate how important the issues are considered for the development of CCS in EnIIs in each of the frames.

	FRAME 1 *IT'S THE SUFFERING INDUSTRY*	FRAME 2 *IT'S THE LACK OF COOPERATION*	FRAME 3 *IT'S THE POLICY*	FRAME 4 *IT COULD BE SOCIAL ACCEPTANCE*
INTERNATIONAL COMPETITION	++	+	-	+
SOCIAL ACCEPTANCE	-	-	-	+
EU ETS	+/-	+/-	++	+
COOPERATION WITH POWER INDUSTRY	-	+	+/-	+
POLITICAL SUPPORT	-	+	+	+
SUPPORT FROM NGOS	-	+	-	+/-

Table 12: Comparison of the four frames using the most important issues

5.3 DISTRIBUTION OF PERSPECTIVES AMONG STAKEHOLDERS

The distribution of respondents over the frames can be found in Table 13. Of the 14 respondents only two do not constitute a defining sort, meaning that only two Q sorts do not load significantly on any of the factors. The distribution of the defining stakeholders over the perspectives should be used in a cautious way, but two general things can be said about it. Perspective 1 is held by only one person who works in the EnII; this might not be surprising since it defends the EnIIs position when it comes to implementing low-carbon technologies. The other conclusion is that frames 2, 3 and 4 are not dependent on the stakeholder's affiliation. The Q sorts of stakeholders for the EnIIs, NGOs and policy makers are spread over the three perspectives.

	FRAME 1 *IT'S THE SUFFERING INDUSTRY*	FRAME 2 *IT'S THE LACK OF COOPERATION*	FRAME 3 *IT'S THE POLICY*	FRAME 4 *IT'S THE SOCIAL ACCEPTANCE*
ENI	1	1	1	2
NGO/RESEARCH	0	1	1	1
POLICY MAKER/POLITICIAN	0	2	1	1

Table 13: Comparison of the four frames using respondents' affiliations

The perspective on the main issues (international competition, lack of cooperation, policy framework or the full package) is not dependent on the stakeholders' affiliations. It therefore makes sense to include stakeholders in a process based on perspectives to ensure that different views are present. A process design in which Q methodology and frames are considered leads to a different process. In the next chapter we will return to if and why such a process is a better process.

5.4 OTHER OBSERVATIONS AND CONCLUDING REMARKS

There are a few other things that are worth a remark that do not fit will in either of the other two sections of this chapter. These observations were done during the 14 Q sort interviews and are worth mentioning because they might be helpful in improving decision-making on CCS in EnIIs.

The first observation is that there seems to be a general indifference or even slightly negative attitude in the EnIIs towards environmental NGOs and the role they can play in bringing CCS in EnIIs further. From the interviews it also followed that cooperation between EnIIs and NGOs is often characterized by distrust.

A second observation follows from the interview with someone from the European Commission's DG Enterprise & Industry: the DG is technology independent and has no specific knowledge on CCS. CCS is considered by the DG as one of the technologies that can reduce emissions from the EnIIs. This is noteworthy since the question could be raised whether the EnIIs have alternative technologies for significant emissions reductions: many research institutions, NGOs and EnIIs themselves believe they do not.

One respondent suggested that the communication on CCS is often framed in energy terms while it could also be framed as a waste technology. If we consider CCS a waste technology, it is easier to accept that there are costs.

The frames teach us something about how stakeholders think about social acceptance. Although social acceptance was considered a key issue by many of the experts that were interviewed when defining the statements, the stakeholders that were interviewed for the Q methodology do not consider social acceptance very important. They believe that when the suitable policy instruments and governance is created social acceptance will follow. This understanding of the problem tells us something about what decision-making should

be about according to stakeholders. How could this be explained? First, the group of people that was interviewed to define the Q sort is mostly working on policy-making, the respondents of the EnIIs that were asked to do the Q sort were much more involved in technological and economic aspects. It could be that latter group of stakeholders overlooks the importance of social acceptance for CCS development. Another possibility is that the role of social acceptance is dependent on the developments phase of CCS in EnIIs. In the current system social acceptance is not considered the most important issues because other issues need to be solved first, most notably a policy framework, stakeholders cooperation and international competition. It could be that social acceptance will become important when those issues have been addressed. Some stakeholders also believe that social acceptance will be created spontaneously by the changing environmental circumstances.
CO2 utilization, although again often mentioned in the first interviews with experts, was not considered one of the important drivers for CCS in EnIIs by the stakeholders. Some considered utilization a set of technologies that could contribute in creating a business case or developing the infrastructures, but more respondents pointed to the small volumes of CO2 that utilization could deal with.

The key conclusion of this chapter is that stakeholders' frames do have a role to play in process management. Where process management is concerned with stakeholders resources and interests, this chapter shows that including stakeholder frames in a process design leads to a different process. The process is different in that selecting stakeholders based on affiliation delivers a different result compared to selecting stakeholders based on frames (section 5.3). Selecting stakeholders purely based on affiliation increases the risk of missing out important stakeholders and views. The role of Q methodology in this study is not so much to identify a complete set of frames (it could be argued that this is not done due to the small P sample), it is to show the importance of Q methodology and frames when designing a process.
The results of this chapter will be combined with the empirical description of CCS in EnIIs (chapter 2) and theory on process management and stakeholder frames (chapter 3) to design a decision-making process for CCS in EnIIs.

CHAPTER 6: ANALYSIS

In this chapter the theoretical and empirical parts will be combined: the theoretical description of a process approach enriched with frames (chapter 3) and the empirical parts: the description of the system (chapter 2) and the identification of frames for stakeholders in the CCS in EnIIs decision-making arena (chapter 5) will be brought together leading to a design for a decision-making process for CCS in EnIIs. It will be explored how the mechanisms explained in chapter three will work for CCS in EnIIs when enriched with stakeholder frames. A first important element that becomes clear from both chapter two and chapter five is that there is no process. If a decision-making process is a process such as described in chapter three, such a process does not exist for CCS in EnIIs in the EU. There is no single platform where relevant stakeholders gather to create an environment in which they take decisions on how to bring CCS in EnIIs further. Since, as argued before, CCS in EnIIs needs a process to bring its development further, such a process design will be given here.

This chapter is structured following seven questions about the process: *Who should take the lead?, Who should participate?, How to ensure participation?, How to ensure support?*, *What should be on the agenda?*, *How to realize progress?* and *How to guarantee the quality?*.

6.1 WHO SHOULD TAKE THE LEAD?

The first question that should be addressed is who should take the initiative to make a process? Who should take the lead in inviting stakeholders to the table and in making process agreements? The best arguments that can be made lead to the conclusion that it is the European Commission that should take the lead here.

First of all, climate change and the abatement of CO_2 emissions is a societal problem. It could be argued that societal problems are to be dealt with by governments. It is not the natural position of the industry to deal with societal problems, industries deal with production problems. But saying that the government should handle this problem because governments should handle societal problems is also to a large extent a political argument. There are more scientific arguments to be made about the leading role the European Commission should play: from the Q interviews it can be concluded that there is a strong distrust between EnIIs and NGOs, making a process initiated by either of those type of stakeholders highly controversial (see section 5.4). The chances of some of the NGOs participating in a process initiated by EnIIs is unlikely, and the same goes for EnIIs participating in a NGO initiated process. To both groups of stakeholders a process started by the European Commission would be much more attractive.

Another argument can be made using the frames that have been found (section 5.2). What do the frames tell about who should take the lead? Clearly, the first frame (suffering industry) points to the European Commission that should do something if we want CCS to happen: the frame clearly tells us that we should not expect much from the industry. The third frame (policy), also clearly points to the commission that should come with policies to bring CCS in EnIIs further. The second frame (cooperation), does not directly point to the commission, but the commission could be the stakeholder bringing the others together. Since the commission is seen as a party that has to weigh the different interests, they are a party that is acceptable to most to take the lead in creating more cooperation. Finally, the ‘full package’ frame does also not directly point to the commission taking the lead but it would be compatible with it.

Finally, the development of CCS in EnIIs can be compared to the development of similar infrastructures such as the railways. Such developments have always been characterized by a strong government involvement in the first phases of the process. Without government involvement in these early stages it is unlikely that the technology will be deployed on a large scale (section 2.6). Later phases can lead to a gradual withdrawal of government involvement when the technology develops to commercially viable levels.
Therefore, in initiating the process the European Commission should take the lead.
Can they take the lead? From chapter two (section 2.5) and some of the interviews it follows that politicians in general are reluctant to speak about CCS due to the low social acceptance: they want to be re-elected. For the European Commission this is less valid: the commission is not elected and can therefore take a more independent position. Secondly, the commission has been outspoken in favor of CCS in EnIIs and acknowledges its role in emissions reduction in their roadmaps. So, yes, the European Commission is in a position to take the lead in this.

6.2 WHO SHOULD PARTICIPATE?

In a process management approach one should consider both interests and resources when deciding who should join the process: at least those actors with production power and some with blocking power should be included and one should make sure all interests are represented in the process (section 3.5). From chapter two (section 2.1) it follows that at least the EnIIs themselves should be included. They are the actors that have the production power for the technology. Should all the industrial companies be included? De Bruijn et al. (2012) state that it could be enough to include representatives of the industries as long as they play the role of an account: via them all the different ideas that live within the industries should be brought into the decision-making arena. When it is possible to realize an account role, there should be no need to include all the industrial actors. One could for example think about giving some companies a seat at the decision-making table while the industries themselves have regular roundtable meetings that are accessible to all companies.
It also follows from chapter two and chapter five that there is a need for policies that incentivize industries to do CCS. Who are the actors that have power over these policies? Clearly, policy-makers and politicians can strongly influence policies. Therefore, there is a need to include them. Again, we can ask the question: do we need to include all of them? No, would be the answer as long as we can ensure that representatives can play the role of an account: bringing all the ideas forward that actors in this group have about CCS in EnII.
What other actors to include? We have seen the case of Barendrecht in which local social resistance blocked a CCS project. How to include those actors in the decision-making? A good way to do this would be to include environmental NGOs that can represent these interests in decision-making. The interim-conclusion here is that actors should be represented in the decision-making process based on their affiliations (industry, policy-maker, NGO), this would only work, though, if they can serve the account function: bringing all the interests of the groups of actors they represent to the decision-making arena.
As can be seen from chapter two (section 2.1) research institutions, industrial associations, national governments and equipment manufacturers also have significant production power and should therefore be included in the process.
An alternative to the idea of an account is to include stakeholders based on their frames. When including

stakeholders based on affiliation with an account function, it is likely that those stakeholders that are most willing to bring CCS forward are willing to participate, while the most reluctant are not included. It is important to include those stakeholders that have a pessimistic view about the future of CCS in EnIIs as well, such as those holding frame 1. In the end, we also need those industries to apply CCS if we want significant emissions reduction in the EnIIs. We need to know what their ideas are on how CCS in EnIIs can be deployed. Therefore, it is proposed to first research what firms hold what perspective and consequently ensure that for each of the perspectives at least one firm is represented in the process. These could play the role of representing the other firms that hold similar problem definitions or frames.

For NGOs the same holds: just including one or a few NGOs and expecting them to play the role of account for other NGOs will not work. Environmental NGOs have quite different ideas on CCS in EnIIs and therefore they should be selected based on their frames rather than their affiliation.

In chapter five it was concluded that the three directorates-general of the European Commission that are most involved in CCS in EnIIs (Climate Action, Industry & Enterprise and Research & Innovation) hold different frames on the matter, therefore they should all be involved in the process.

Thus: next to the usual suspects, stakeholders with different perspectives should also be included. In order to realize that, a study will have to be done to the different views stakeholders hold and include them based on the uniqueness of their frame.

6.3 HOW TO ENSURE PARTICIPATION?

Stakeholders that have reluctance towards or even strong objections against CCS in EnIIs are not likely to join the process. They might be afraid that they support a process that leads to something that goes against their interests. Greenpeace, for example, is an opponent of CCS (section 2.5) and will therefore be quite unwilling to join. Still, inviting them to participate in the process can provide the process with more legitimacy and enrich problem definitions. How could Greenpeace be convinced to join? First of all, it could be argued that Greenpeace represents a unique frame on CCS in EnIIs that should be represented in the decision-making. If they are not represented they have limited means to influence decision-making. This is a message that should be brought to them. Secondly, to make it attractive for them to join, maybe the decision-making issue should be framed differently as 'How to reduce the emissions from EnIIs?' rather than 'How to realize the deployment of CCS in EnIIs?' It is likely that Greenpeace would like to have a stake in thinking about how to reduce the EnIIs' emissions. How do we ensure the participation of reluctant industrial firms such as those holding frame 1 (section 5.2)? Again, we should formulate it in an attractive way: 'how to ensure long-term production of EnIIs in the EU?'. Surely, this brings other items to the agenda as well, which initially might slow the process down, but for an issue such as CCS in EnIIs we need all stakeholders to be involved, if that can be reached by broadening the agenda, we need to do that. Ultimately, it would be best to formulate a question that is attractive to all stakeholders, both industries and environmental NGOs. The question could be formulated as: 'how can we realize a long-term low-emission EnII in the EU?'. In this way a meta-frame is created in which all stakeholders find themselves at ease.

Next to framing the issue in an attractive way, stakeholders' core values should be protected as well. At least, in the beginning, before social learning has occurred, it should be clear to reluctant stakeholders that their core values will not be debated. EnIIs should not be asked in the beginning to be open about their production costs and NGOs cannot be asked not to inform their members or supporters about the process.

Participation should also be realized from the three Directorates-general of the European Commission. Two of the three (Climate Action and Research & Innovation) have specialists on CCS in EnIIs and seem dedicated to bring CCS further, but Directorate-general Industry & Enterprise does not. They state that they are technology neutral and do not favor one emission abatement technology of the other (section 5.4). Therefore, their commitment to the decision-making process on CCS in EnIIs is limited. This DG would also be attracted though by formulating the decision-making issue at hand more broadly. Alternatively one could argue that this technology-neutrality is unrealistic, since the fact is that there is currently no other technology available that can realize meeting the EU's emission reduction targets (section 1.1). Since their participation is crucial in shaping industrial and environmental policy the European Commission should ensure that this Directorate-general is more dedicated towards CCS in EnIIs and is thus a full participant of the process.

6.4 HOW TO ENSURE SUPPORT?

Participation of relevant stakeholders is one important aspect, support of the larger audience another. Even when involving all relevant stakeholders, there could still arise a lack of acceptance by the larger public leading to implementation problems (from a pragmatic point of view) and lack of democratic legitimacy (from a normative point of view). Selecting stakeholders based on stakeholder frames can induce public acceptance. Here, it is all about substantiating. It is about the arguments used to reach a certain decision. In a process built upon interests and resources (such a process management without stakeholder frames) a proper argumentation based on different views is not needed to reach decisions: it is about bringing a group of actors together that have an interest in reaching a common goal and have all the needed resources available. There is a need to include the interests of other parties in the argumentation, but in a process managerial approach this would be enough. This makes that in the argumentation there is no need to include other world views, creating the risk of unacceptance by the other stakeholders that feel their views are not considered: they feel the real world is functioning very differently from how the key decision-makers view the world. Decision-making between stakeholders based on frames require argumentation that include the different frames and therefore can create better acceptance by stakeholders. It would thus not be enough to defend a decision using different interests ("it is good for the industry, it is what NGOs want and it does not cost much for tax payers"), but also using different frames that have been found (see section 5.2): this decision can create public acceptance, enhance governance, is the right policy and takes into account that EU's industry is facing difficult times. When including frames in a process design, stakeholders within the process make sure their world views are included in the argumentation and therefore the final decision is more likely to be acceptable to all stakeholders and the larger public.

So, what is the practical implication of this for the process? First, the process' participants should be selected based on frames (as already argued in 6.2). Consequently, within the process of decision-making these frames should be considered. One can imagine that for each decision that is taken a part of the argumentation is devoted to explaining how the frames are taken into account for this decision. This reduces the risk of public resistance. Although, this mechanism can lead to better social acceptance its strength is limited: a large part of the greater audience will not spend time on reading through the decision-makers' argumentation and might therefore still be unwilling to accept the decisions and feel that participation has been too limited. A next option would be to find frames that exist amongst the larger audience by also doing a Q research. The frames that have been found in that study should also be included in the argumentation for decisions. Both these mechanism can work in increasing social acceptance (from instrumental, substantive and democratic points of view), but they are no final solution to it. It should be recognized that the study field of social acceptance is broad and complex and the scope of this study is limited.

6.5 WHAT SHOULD BE ON THE AGENDA?

Process management proposes a broad multi-issue agenda. A multi-issue agenda creates interdependencies: stakeholders need to cooperate since they might need each other to reach their own objectives. Therefore, many of the issues that have been described in chapter two should be on the agenda. In that way a context is created in which actors help each other reaching their objectives. For example, putting on the agenda both R&D of more cost-effective technologies for capturing CO2 (section 2.4) alongside research to environmental consequences for the ecosystem of CO2 leakage in the seas (section 2.5) can create support from both industries and NGOs. When only one of the items would be put on the agenda, the stakeholders would not have supported each other. The list of items that should be addressed follow from chapter two. First issue is the technology (section 2.2). How much do we know about these technologies: what are the costs and where is the need for R&D? Pilot, demonstration and commercial projects should be discussed: what is needed the most? Economic policies should be discussed: what mechanism works best in incentivizing industries, how to deal with international competition and carbon leakage, what support mechanisms should become available, how to deal with other market imperfections such as networks characteristics, development of transport infrastructure and monopoly power and how to provide financing for CCS projects? Legal issues should be addressed such as the London protocol and environmental impact assessments. Social issues should be placed on the agenda: NIMBY character of CCS projects, perceived risks of environmental disasters, reduced development of renewables and the continued use of fossil fuels. Political issues that should be discussed include: international climate agreements, energy supply security and volatility of legislation. Potential drivers for CCS such as sectorial agreements, CO2 utilization or BECCS should be discussed (section 2.3 and 2.4).

Although all these issues are very important for the development of CCS in EnIIs it is proposed to first take a step back. As argued in section 6.3 some stakeholders might be reluctant to participate and a proposed solution was to formulate the decision-making issue is a broad way: 'how can we realize a long-term low-emission EnII in the EU?'. Therefore, the first issues that should be on the agenda should be related to this very general question. One could imagine first discussing to what extent emissions reduction should be realized. Consequently, alternatives for low-emission technologies could be discussed. What would be the costs of these alternatives? So, then what would be the most cost-effective technologies to reduce emissions? After having discussed these questions, more specific one's such as those mentioned above could be dealt with.

Clearly, there is a need for prioritization in these more specific issues, not in the beginning when inviting stakeholders, but when they are at the decision-making table and trust has been created. The risk of prioritization is that items are initially neglected that stakeholders consider of major importance. Therefore, the best thing to do would be to find the items on this list that stakeholders find the key issues that should be addressed first. The four frames that have been found clearly indicate what issues should be addressed with priority (section 5.2) according to a group of stakeholders. It indicates what stakeholders consider the most important items behind all the other: international competition (frame 1), stakeholder cooperation (frame 2), a policy framework (frame 3) and, to a lesser extent, social acceptance as part of the full package (frame 4). It is making the frames explicit that shows that a group of stakeholders, both NGOs and EnIIs, consider cooperation between stakeholders the main issue. When then only addressing international competition and a policy framework, one is not solving what a group of stakeholders consider the real issue. Therefore, mapping stakeholder frames can help prioritize the list of issues. In this way a prioritized multi-issue agenda can be created.

6.6 HOW TO REALIZE PROGRESS?

Process management suggests that progress could be induced by organizing conflict deep in the process (section 3.5). It entails to make sure that conflicts between stakeholders are outspoken in the lowest possible organizational structure of the process (in a working group rather than the steering group with high level representatives). Due to the organization of conflict stakeholders learn about each other's positions and gain better information on all aspects of CCS in EnIIs. It should be organized low in the process though, so that the highest representatives in the higher steering group are not damaged by this conflict while they do have the gains from it (explicit viewpoints and better information). These gains lead to progress in decision-making. Including frames in a process can lead to another benefit. When stakeholders in the lower parts of the process are forced or tempted to make their viewpoint or frames explicit it leads, next to better information, also to social learning. An example that was experienced during two Q interviews with representatives from the EnIIs: the respondent took the statement about NGOs ('It would help if more environmental NGOs would be in favor of CCS in EnIIs') and immediately put the statement to the left side (most disagree). After telling them that some respondents ranked the statement more positive with the argumentation that NGOs can create more social acceptance they agreed with this and put the statement more to the right. This example shows that stakeholders can learn from each other's viewpoints and that frames can converge. When this occurs it creates opportunities for progress. So do the four frames that have been found show that they can converge or are they contradictory? Although the four frames each point to a different aspect of CCS in EnIIs as the most important issue they are also to a large extent complementary rather than contradictory. It is very well possible that when frames are made explicit stakeholders realize that in order to do something about international competition the right policy framework needs to be created, for that cooperation amongst stakeholders and social acceptance needs to be dealt with.

Then how to ensure that these frames are made explicit and social learning can occur? One way to incentivize an open conversation between stakeholders is to protect these lower organizational structure by closing the discussions for the outer world. When stakeholders can be sure that what they say in these meetings will not be published in any sort of way they will be more willing to participate in an open discussion. It is easier for NGOs to say an industry is right about something when the larger public is not immediately informed. After stakeholders in the lower structures have found commonalities in their world views they can bring it to the higher structures and representatives that could think about how to communicate the message to the public.

Progress can be incentivized by making frames or world views explicit in a protected environment which stimulates social learning among stakeholders. Rather than organizing conflict in the lower levels it is proposed to organize social learning in the lower levels of the process.

6.7 HOW TO GUARANTEE THE QUALITY?

The above questions do not address the quality of decisions. When designing and managing a process according to the answers above there is no guarantee that decisions will be taken that can be executed. Decisions could be meaningless. Process management recognizes two mechanisms that can increase the quality of decisions: from variety to selection and involving experts (section 3.5).

The mechanism to work from a variety of options to a selection can be used very well in the case of CCS in EnIIs. When first posing the question 'How can we realize a long-term sustainable EnII in the EU?' several options are open: increasing efficiency through recycling, fuel substitution, energy recovery, application of the best available technologies and CCS (section 1.1). Finally, it could turn out that CCS is the alternative that can realize the greatest emission reduction for the lowest costs. When starting with a great variety at the beginning of the process, there is a guarantee that the best alternative at least has been considered. One could even consider including other options at the beginning of the process such as drastically decreasing production of the EnIIs. When all of these alternatives are considered, it is harder for stakeholders to question the final outcome of the process. Of course, it could also be possible that CCS is not further considered as one of the best alternatives. This should not be a concern to the most important stakeholders: the decision-making process should have a low-emission industry in the EU as its objective rather than CCS in the EU's industry. The fact is that most stakeholders believe that CCS is the best fitting technology and it is therefore unlikely that CCS will not be considered one of the best alternatives.

The involvement of experts in the process has to be carefully managed. Just letting experts do their research and present the results often leads to non-acceptance of a group of stakeholders. Stakeholders should have the opportunity to shape the research objectives and question the expert during the study. Experts can play a role in making explicit the research assumptions, boundaries and data-usage, in other words, they can help stakeholders in interpreting the results and use the knowledge in decision-making. One of the most difficult issues as we have seen in section 2.5 and 2.6 is carbon leakage: the relocation of EnIIs to parts of the world with less stringent emission reduction legislation. Studies to the sensitivity of carbon leakage can be highly controversial. Experts can help in explaining the assumptions and boundaries of the study, making the arguments of stakeholders and, in that, the decisions of better quality.

CHAPTER 7: CONCLUSION

In this chapter conclusions will be drawn from this study. First let us recap the main research question:

> *How can process management, enriched with stakeholder frames, be used to improve the decision-making on carbon capture and storage in energy-intensive industries in the European Union?*

Carbon capture and storage (CCS) is a CO2 emissions abatement technology that comprises the capture of CO2 at industrial point sources such as factories or power plants, the transport of CO2 trough pipelines or by ships, and the permanent geological storage of CO2. The technology can be used to mitigate emissions from fossil fuel power generation or Energy-Intensive Industries (EnIIs) The need for CCS in EnIIs for meeting EU's emissions reduction targets and thus limiting the negative consequences of climate change has been acknowledged by many, but the development of it in the EU is lagging behind. Decision-making on CCS in EnIIs is highly troubled by contrasting interests, resource interdependencies and different perspectives on the matter. This study aims to come up with recommendations on how the decision-making process could be improved.

The first paragraph will describe the system of CCS in EnIIs. It thus provides an answer to the first sub research question. The second paragraph describes how process management can be used for decision-making on CCS in EnIIs and what role stakeholder frames can theoretically play in improving a process design (sub question two). The third paragraph answers the third research question and in doing that describes the frames that have been found that stakeholders use to understand CCS in EnIIs. The final paragraph provides an answer to the main research question and, in doing that, gives recommendations on how decision-making in CCS in EnIIs can be improved.

7.1 CCS IN ENIIS

The first sub research questions '*What does the CCS in EnIIs system look like?'* was dealt with in chapter two. Theories of socio-technical change can be used to provide a framework for understanding phenomena in which technological aspects are intertwined with economic, political, social and cultural dimensions. They state that a socio-technical system comprises three types of elements: actors, technologies and institutions.

The main actors in the field of CCS in EnIIs include the industrial companies in the EnII sectors: steel, cement, chemicals and refining that have significant power over decision-making due to their knowledge, financial resources and their role as major employer. Secondly, European government institutions such as Directorates-general Climate Action, Research & Innovation and Enterprise & Industry of the European Commission, the European Parliament and the European Council play a major role since they have decision-making power over legislation and can influence the public opinion. The role that environmental NGOs can play in both bringing CCS forward (some) and promoting alternatives for CCS (others) is mainly due to the shaping of public opinion. Finally, research institutions, industrial associations and other organizations can influence decision-making using their knowledge and network.

CCS technology is not new, elements of it have been applied for many years. Currently, there are only few large scale integrated commercial projects. Capture technologies are various but can be categorized in pre-process, post-process and oxyfuel. Pre-process carbon capture that can be applied to coal-fired power stations or other industrial emitters that use carbon-containing fossil fuels or biomass entails the transformation of the fuel into hydrogen and CO2 before the industrial process. The hydrogen can then be used as fuel after separation from the CO2 and the concentration of the remaining CO2 will be high enough for transportation. Post-process entails the separation of CO2 from the other flue gases (mostly N2) at the end of the industrial process. This can be done by a chemical process using an amine solvent or physically using a membrane. A third technology is oxyfuel carbon capture; fuel is burned in an oxygen rich environment (without N2) leading to mainly CO2 as product. The transport of CO2 is most likely to be done by pipelines, although liquefied CO2 shipping could be more cost-effective in some instances. Finally, three main options for storage of CO2 have been identified: deep saline aquifers (salt-water bearing rocks), depleted oil and gas fields and deep unmineable coal beds. CO2 is trapped at a depth of at least 800m under pressure and temperature conditions such that the CO2 is liquid. The trapping can be either physically or chemically in a porous formation, while above this there should be a layer of impermeable rock.

Institutions, defined as formal or informal rules that guide human behavior, play a major role in CCS in EnIIs. In this study a categorization has been made in barriers and drivers. Economically, main barriers include the lack of suitable mechanisms that provide incentives for industries to abate CO2 emissions. The EU Emissions Trading Scheme seems to be failing for these industries due to the low prices of allowances. Moreover, many EnIIs are provided with free allowances due to the risk of carbon leakage: the relocation of EnIIs to regions of the world with less stringent emissions abatement legislation. Alternative policies could potentially provide better incentives but many believe that international competition makes that all of these mechanisms should be complemented with policies to prevent carbon leakage. The development and governance of a CO2 infrastructure constitutes an other major barrier due to the network characteristics and complementarity of capture, transport and storage. The social dimension is strongly influencing the development of CCS as well: public resistance has stopped CCS projects and continues to shape the decision-making. CCS projects typically have the characteristics of Not In My Backyard projects due to the perceived risks of CO2 leakage, earthquakes and the like. Although off-shore storage largely mitigates social resistance, pipeline infrastructure development can still be stalled by it. Furthermore, by some, most notably some NGOs, CCS is not considered an suitable technology in tackling CO2 emissions due to the increased energy use, environmental risks, continued use of fossil fuels and competition with renewables. These arguments reduce the support for public funds being used for CCS. Although of less importance, legal issues also constitute a barrier to CCS development. One of the main drivers for the development of CCS in EnIIs is an international climate agreement on global emissions reduction. In the absence of such an agreement industrial sectorial agreements could create a context in which CCS would develop. Other drivers include CO2 utilization in enhanced oil recovery, construction materials or fuel production, CCS combined with biomass (which has the potential of negative CO2 emissions). Alternatively, the society could decide that CCS should largely be paid with taxes and create support schemes for the industry. For that it would be needed the create more public acceptance.

7.2 THEORY: PROCESS MANAGEMENT AND STAKEHOLDER FRAMES

In this section the second research question will be answered: '*Why and how can process management help in improving decision-making on CCS in EnIIs?'*.

As can be seen from the last section, CCS in EnIIs can be characterized as a multi-actor problem in which actors are dependent on each other due to the distribution of resources amongst them. In order to bring CCS in EnIIs further the actions of actors have to be aligned, resources need to be shared. For a CCS project to continue industries need to change their production processes, financers need to provide funds, government need to provide a legislation and legitimacy, research institutions provide knowledge and NGOs can help in gaining public acceptance and legitimacy. This is what is called resource interdependency of actors. This would not constitute a problem for decision-making as long as actors share the same interests and objectives; obviously this is not the case for CCS in EnIIs. Industries want to make profit, NGOs battle emissions, unions want employment and governments need to balance interests. How can decision-making be managed for such an issue? Process management is a decision-making model that fits well with such network decision-making processes with resource interdependency and contradictory interests. A process management approach can reduce information uncertainty, enrich problem definitions and solutions, incorporate dynamics, create transparancy, depolitize and attract support. To realize these advantages of a process design four design criteria have to be taken into account. A process needs to be open, meaning that alle the interests of stakeholders would be brought to the decision-making table; directly by stakeholders themselves or via a representative: an account. Open means both open to participants and an open agenda. An open agenda creates the risk that some stakeholders will feel unsafe since an issue might be on the agenda that touches upon some of the core values of stakeholders and they might leave the table. The second design criterion is therefore to protect stakeholders' core values. A process also needs enough progress, it needs it since the objective is to get somewhere, but also to show people that the process approach works: to gain legitimacy for the process design. Finally, the quality of the decisions is a concern. Many process designs and management mechanisms are available to meet these four criteria. But the process management approach has its limitations: in this study an attempt is done to overcome some of these limitations by enriching the process management approach. The core of the critique on the process management approach is its focus on interests and resources of actors. Including the perspectives, world views or frames, defined as the set of ideas that actors hold about how the world around them functions, of actors on CCS in EnIIs in a process approach can improve the design for five reasons.

First, selecting participants based on resources or interests could lead to a process where certain frames are not represented and thus not considered. Lacking knowledge on such information could lead to problems when implementing the taken decision. Including frames in a process design can further reduce information uncertainty. The second reason, enrichment of problem definitions and solutions: surely the proposed process design can lead to enrichment of problem perceptions and solutions, but the understanding of the problems and solutions could be further enrichment by including more world views or frames in the process. Enriching the decision-making with stakeholder frames can increase the quality of the decisions taken because they are based on a more comprehensive understanding of social reality. Third, support from the larger audience for decisions could be improved by incorporating different frames in the decision-making process. When stakeholders realize their ideas were not considered in the decision-making process they will be more reluctant to support the decision that has been taken. Fourth: in process management the focus is on the instrumental and substantive rationales for participation rather than the normative rationale. Including frames in a process design can provide democratic legitimacy because it gives stakeholders the message that their world view is considered in the decision-making process. A last argument that can be made against the proposed process design is that there are opportunities for creating a more deliberative process. Social learning takes place through insight in each other's perspectives or frames. When stakeholders understand where viewpoints or values stem from, from what world view they are derived, it is easier to learn from each other. Within the process management approach this element seems underrepresented.

7.3 STAKEHOLDER FRAMES FOR CCS IN ENIIS

This section answers sub research question 3: '*What frames can be identified that stakeholders use to understand CCS in EnIIs?'*. Q methodology was used to come to an answer to this question. Q methodology aims to capture the frames that stakeholders use to think about CCS by asking respondents to sort a number of statements and make their argumentation for the sort explicit. In this study Q interviews were conducted with 14 stakeholders from the industry, NGOs, policy-making, politics and research. They were asked to sort 31 statements about barriers, drivers, problems and potential solutions for CCS in EnIIs that were collected from open interviews (prior to the Q interviews) and literature. Consequently, their sort were factor analyzed to find frames. Open interview questions helped in interpreting the factors.

The role of Q methodology in this study is not to find the complete set of frames that exist among stakeholders, it is to explore how these frames can be used to improve a process management design.

Four frames have been found:

1) It's the suffering industry, stupid!
   In this frame the cause of the lack of development is that the European industry is suffering from decreasing profits due to lower demand, higher energy costs and international competition. At this moment we cannot ask the industry to battle CO2 emissions, because they simply will not be able to pay for it. If we want to progress CCS in EnIIs, either international climate agreements have to be reached or tax payers will have to pay it.
2) It's the lack of cooperation stupid!
   International competition means that it is hard for the European industry to reduce emissions. But another main issue is that stakeholders are not cooperating well. Environmental NGOs and politicians should be more outspoken in favor of CCS in EnIIs and we need industry wide cooperation. An open dialogue and creating trust between the industry and policy-makers is important.
3) It's the policy, stupid!
   International competition is not the main issue, it is the lack of a functioning EU policy framework. The key issue is that the EU's Emission Trading Scheme (ETS) is not incentivizing EnIIs to do CCS. Maybe we need another mechanism or improve the current mechanism. Politicians can take the lead in shaping the right policies to make CCS happen.

4) It's the whole package, stupid!
   The EU ETS is indeed not functioning well, stakeholder cooperation could be improved and the industry is facing international competition, but social acceptance is an issue as well. We cannot bring CCS in EnIIs further if we not address all of these four issues.

Other conclusions that follow from the interviews are:

- social acceptance is not one of the key issues in CCS for EnIIs according to many stakeholders;
- there is a strong distrust between some EnIIs and some NGOs;
- Directorate-general Industry & Enterprise of the European Commission is technology-neutral and considers CCS as one of the emissions reduction technologies for the EnIIs;
- CO2 utilization is not an important driver for CCS in EnIIs to many stakeholders.

Finally, this study clearly shows that the distribution of stakeholders among the frames is not dependent on stakeholders' affiliation (industry, NGO, policy-maker) with the exception of frame 1. This leads to the conclusion that a process design based on stakeholders frames does look different than a standard process design in which stakeholders are selected based on affiliations. Selecting stakeholders based on frames leads to a different process which can better accommodate some characteristics of decision-making processes such as CCS in EnIIs as will be shown in the next paragraph.

7.4 IMPROVING DECISION-MAKING ON CCS IN ENIIS: PROCESS MANAGEMENT AND FRAMES

In this section the main research question will be answered:

> *How can process management, enriched with stakeholder frames, be used to improve the decision-making on carbon capture and storage in energy-intensive industries in the European Union?*

The question has been answered using the three previous parts: the empirical description of the system of CCS in EnIIs, the theoretical part on process management and stakeholder frames and the empirical identification of these frames.

The first important conclusion that can be drawn from this research is that currently a decision-making process is missing. There are no stakeholders taking the initiative to gather all relevant stakeholders and discuss what decision should be taken. In a context with resource interdependencies, contradictory interests and different views a process is the type of decision-making that is needed. This section describes how such a process could be designed and managed. The main research question is answered by describing what a decision-making process should look like using seven questions: *Who should take the lead?, Who should participate?, How to ensure participation?, How to ensure support?*, *What should be on the agenda?*, *How to realize progress?* and *How to guarantee the quality?.*

From this study it follows that it is the European Commission that should take the lead in initiating the process. One could argue that societal problems are to be dealt with by governments, since the European Commission is the governmental organization that strongly guides environmental policy, this would be the institute to take the lead. Secondly, in similar technologies, such as the development of railways, there has been a need for strong government involvement in the early stages. When analyzing the frames the same conclusion should be drawn: two of the four frames (suffering industry and policy) point directly to the commission, while it would be compatible with the other two frames if the commission would take the lead. Finally, there is a sense of distrust between EnIIs and NGOs, a process initiated by either of them has a high opportunity of failing; a process initiated by the commission has a higher chance of being acceptable to all stakeholders.

Based on power and interests the participants of the process should at least consist of representatives from the EnIIs, NGOs, the three involved Directorates-General of the European Commission (Climate Action, Research & Innovation and Industry & Enterprise), research institutions, industrial associations, national governments and equipment manufacturers. Process management proposes to let stakeholders play the role of an account and in that way represent the interests of their group of stakeholders, this to ensure that the process remains manageable while all interests are represented. When having knowledge on stakeholder frames one should conclude that stakeholders in the same group (steel industry, NGO, etc.) can hold very different frames. Therefore, the chances of having all views represented are larger when ensuring that all frames are represented as well. Practically, this means a study has to be done to what problem definitions stakeholders hold and ensure that all frames are represented in the process.

There would still be a chance that some of these stakeholders are not willing to take part in the decision-making process because they fear it will be against their interests. To realize participation the decision-making process should be framed in a broad manner such as to accommodate the participation of reluctant stakeholders. Instead of 'how can we bring CCS in EnIIs forward?' one should frame the issues as 'how can we realize a long-term low-emission EnII in the EU?'. By creating such a meta-frame, it would be attractive to critical NGOs or EnII firms to join to process. Secondly, their core values will have to be protected: stakeholders will have to get the guarantee that they will not have to do anything that goes against their *raison d'etre* such as giving insight in production processes for industries. Finally, it is again the European Commission that should guarantee the full participation of the Directorates-general. Currently, Directorates-General Industry & Enterprise is not dedicated to CCS technology, while they are a key player.

Public support can be increased by designing the process in such a way that different viewpoints are taken into account when building up an argumentation for a decision. This can be reached by 1) selecting participants of the process based on stakeholder frames and 2) by demanding that each of these frames is considered when taking a decision. A second way to gain public support is to extent the analysis of frames to the larger audience using Q methodology. In this way the bigger public is less likely to oppose a taken decision since their view has at least been considered. Still, the study field of social acceptance is broad and complex and we do not claim here to have an ultimate solution to the social acceptance issue.

What should the decision-making agenda look like? What issues should be on the list? First, the agenda should be kept as broad as possible the ensure participation of all important stakeholders. Therefore first issues should be addresses such as the need for CCS in EnIIs, the extent of emissions reduction and potential alternatives before going into more detailed questions. When these issues have been addresses more specific issues could be dealt with. The technology should be on the agenda: how much do we know about these technologies; what are the costs and where is the need for R&D? Pilot, demonstration and commercial projects should be discussed: what is needed the most? Economic policies should be discussed: what mechanism works best in incentivizing industries, how to deal with international competition and carbon leakage, what support mechanisms should become available, how to deal with other market imperfections such as networks characteristics, development of transport infrastructure and monopoly power, how to provide financing for CCS projects? Legal issues should be addressed such as the London protocol and environmental impact assessments. Social issues should be placed on the agenda: NIMBY character of CCS projects, perceived risks of environmental disasters, reduced development of renewables and the continued use of fossil fuels. Political issues that should be discussed include: international climate agreements, energy supply security and volatility of legislation. Potential drivers for CCS such as sectorial agreements, CO2 utilization or BECCS should be discussed. This does not gives much guidelines on what should be prioritized. Stakeholder frames do give ideas about the prioritization. According to the different frames the most important items are international competition, stakeholder cooperation, the policy framework and, to a lesser extent, social acceptance.

Progress of the decision-making process can be increased by organizing social learning deep in the process. When ensuring that stakeholder frames are being made explicit in the lower organizational structures of the process, stakeholders are incentivized to learn from each other's views and gain insights. This should be done in a protected closed environment, so that stakeholders feel free to 'move' their viewpoints. When this deliberative process has been completed the results can be brought to the higher decision-making level to facilitate progress in decision-making.

Finally, the quality of the decision taken can be improved by working from a variety of alternatives to selection; in the beginning of the process all options should be on the table such as reducing production and energy efficiency next to CCS, even if this leads to the potential risk of excluding CCS from the solution space. This would lead to the best alternative being selected. Secondly, involving experts to make assumptions and boundaries of studies explicit in for example studies on the environmental consequences of CCS in EnIIs can improve the quality of decisions.

CHAPTER 8: DISCUSSION

The conclusions drawn in the last chapter will be placed in perspective in this chapter. How valid and reliable are these conclusions? How can we understand these conclusions in a broader theoretical and societal context and what new research topics arise from them?

8.1 VALIDITY AND RELIABILITY

The core of this study is to map the frames through which stakeholders perceive CCS in EnIIs. Construct or measurement validity addresses the question how well the used methodology is able to do that. Theoretically, Q methodology is well equipped to find frames. Practically, a number of issues arise when applied to the case at hand here. The first issue is that of the respondent selection. Many stakeholders were invited for an interview but only 14 agreed to having one. CCS in EnIIs is controversial making some stakeholders reluctant to speak about it, such as some NGOs and some industrial firms. Secondly, some stakeholders had the idea that their knowledge of CCS in EnIIs is too limited. Although both arguments are valid from the stakeholder point of view, from a research perspective this leads to potentially biased results. It is exactly those stakeholders that are most reluctant that might have interesting and different views on the matter. Since in this study the development issues of CCS in EnIIs are researched it would have been interesting to see how the most reluctant or least knowledgeable stakeholders think about the matter and it could have provided more insights in how decision-making should be designed to also include those that are most reluctant.

A second issue related to construct validity is the interpretation of the statements in the Q methodology: some respondents had little knowledge on some of the statements or interpreted them differently than other respondents. Although, this issue can be partially dealt with by using the respondents' clarification for the sort, for some statements this was not fully possible. For example the statement about carbon border adjustment was not understood by some respondents. A solution to this could be to conduct more test interviews with stakeholders.

When it comes to the internal validity (whether the conclusions that have been drawn follow from the study) especially one conclusion should be critically reviewed: social acceptance is not a key issue. Stakeholders do not consider social acceptance a key issue, can we therefore draw the conclusion that it is not the first thing to address in decision-making? It can be argued that decision-makers such as those interviewed in this study overlook the importance of social acceptance. They might consider social acceptance of lesser importance but as one expert put it "how do we know social acceptance is not an issue if we are not deploying CCS yet?". What about reliability, the concept that captures how well this research can be reproduced with the same results? When it comes to selecting the statements the concern is not too great: although the selection could have been different, it is ultimately the respondents that given meaning to the statements by doing the Q sort. As long as the most important issues are covered the exact set of statements that is selected for the Q sort is not of great importance. The selection of stakeholders is biased though, due to the lack of cooperation of some stakeholders that are quite reluctant towards CCS. This leads to the potential missing out of some frames in the final results. One should keep in mind, though, that the role of Q methodology in this study is not to find a complete set of stakeholder frames, but to explore how stakeholder frames can improve a process management design.

8.2 GENERALIZABILITY

How well are the conclusions transferable to other societal issues? The conclusion about the importance of social acceptance should be treated very carefully. CCS in EnIIs might be comparable with other environmental issues (such as renewables or pollution abatement technologies) in its economic aspects: international competition and the need for support policies, but when it comes to social acceptance it might not be comparable. It might be that the development stage determines the importance of issue. The discussion about renewables (especially wind) and nuclear power is clearly less economic and more social. That is because for those technologies a business case has been created by introducing support policies: the economics get less important and social acceptance more important. For CCS in EnIIs, first an economic case has to be made according to stakeholders, and the social acceptance will gain importance in later phases of the technology's development . It could also be debated whether the conclusions hold for CCS in power: CCS in power has more issues of social acceptance than CCS in EnIIs due to the fact that power generation emissions can be mitigated with other technologies than CCS while EnIIs' process emissions are hard to abate without CCS.

The approach to include frames in process management could be applicable for other issues as well though. In issues where interests seem contradictory and resources interdependencies exist (unstructured problems), insight in frames can create a deliberative environment in which stakeholders can find commonalities and make them realize that they can come to decisions that fit within their ideas on how to bring progress to the world. Typically, environmental issues have such characteristics. In environmental issues, such as climate agreements, forcing stakeholders to think further than their own interests and resources can create the momentum to come to decisions acceptable to all.

8.3 FURTHER RESEARCH AND IMPLICATIONS

Finally, something can be said about further research. A next step in developing a new process management would be to test it. Would it really work to make frame explicit to stakeholders? Would decision-making be more deliberative, would more social learning occur? Would stakeholders support decisions more? Would the quality of the decisions be better?

Another interesting type of research would be whether stakeholders agree with the frame they are being placed in. If they do not, that can tell us three things: the analysis in this study has not been executed carefully enough, stakeholders are not aware of the way they think about the issue or frames are dynamic, meaning they change over time.

With relation to CCS in general and CCS in EnIIs many research issues remain. Following from this study are three important research topics: international competition, stakeholder cooperation and policy framework.

International competition is closely related to carbon leakage and carbon border adjustment, a broad research field in which a lot of research has already been done and is currently being executed. The sensitivity of industries for carbon leakage has been researched using the industrial sector's characteristics, but it could be interesting to study it from a stakeholder perspective. How do stakeholders think about the chances of industries leaving the EU when more stringent regulation is implemented? Cooperation between stakeholders would offer many opportunities for further study. What scenarios can be thought of with what consequences for decision-making? Finally, the policy framework has already been extensively studies, but definitely offers more opportunities.

Finally, what should be said about the value of this study? This study shows that in decision-making on complex issues with contradictory interests, resource interdependencies and different views on problems and solutions a process is needed. When enriching this process design with stakeholder frames, using Q methodology, a higher quality process can be created. Selecting stakeholders based on stakeholders frames, making those frames explicit and designing a broad agenda leads to a decision-making process that is better capable of reaching fitting and broadly acceptable solutions, since the process better represents the different ideas that live among stakeholders.

REFERENCES

Addams, H., & Proops, J. L. (2000). *Social discourse and environmental policy: an application of Q methodology*: Edward Elgar Publishing.

Barry, J., & Proops, J. (1999). Seeking sustainability discourses with Q methodology. *Ecological Economics, 28*(3), 337-345.

Bodansky, D. (2007). *International sectoral agreements in a post-2012 climate framework*: Pew Center on Global Climate Change.

Boot-Handford, M. E., Abanades, J. C., Anthony, E. J., Blunt, M. J., Brandani, S., Mac Dowell, N., . . . Hallett, J. P. (2014). Carbon capture and storage update. *Energy & Environmental Science, 7*(1), 130-189.

Bradbury, J., Greenberg, S., & Wade, S. (2011). Communicating the risks of CCS. *Washington DC: Wade LLC*.

Brown, S. R. (1980). *Political subjectivity: Applications of Q methodology in political science*: Yale University Press New Haven, CT.

Brown, S. R. (1993). A primer on Q methodology *Operant Subjectivity, 16*(3/4), 91-138.

Brown, S. R. (1996). Q methodology and qualitative research. *Qualitative health research, 6*(4), 561-567.

Brunsvold, A., Jakobsen, J., Husebye, J., & Kalinin, A. (2011). Case studies on CO2 transport infrastructure: Optimization of pipeline network, effect of ownership, and political incentives. *Energy Procedia, 4*, 3024-3031.

Bryson, J. M. (2004). What to do when stakeholders matter: stakeholder identification and analysis techniques. *Public management review, 6*(1), 21-53.

Carbo, M. C. (2011). *Global Technology Roadmap for CCS in Industry: Biomass-based Industrial CO2 Sources: Biofuels Production with CCS*: ECN.

Chrysostomidis, I., Zakkour, P., Bohm, M., Beynon, E., de Filippo, R., & Lee, A. (2009). Assessing issues of financing a CO2 transportation pipeline infrastructure. *Energy Procedia, 1*(1), 1625-1632.

Ciupuliga, A., & Cuppen, E. (2013). The role of dialogue in fostering acceptance of transmission lines: the case of a France–Spain interconnection project. *Energy Policy, 60*, 224-233.

Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A garbage can model of organizational choice. *Administrative science quarterly, 17*(1).

CONCAWE. (2011). The potential for application of CO2 capture and storage in EU oil refineries: European Oil Company Organisation for Environment, Health and Safety.

Cosbey, A., Droege, S., Fischer, C., Reinaud, J., Stephenson, J., Weischer, L., & Wooders, P. (2012). A Guide for the Concerned: Guidance on the elaboration and implementation of border carbon adjustment.

Cross, R. (2005). Exploring attitudes: the case for Q methodology. *Health Education Research, 20*(2), 206-213.

Cuppen, E. (2012). Diversity and constructive conflict in stakeholder dialogue: considerations for design and methods. *Policy sciences, 45*(1), 23-46.

Cuppen, E., Breukers, S., Hisschemöller, M., & Bergsma, E. (2010). Q methodology to select participants for a stakeholder dialogue on energy options from biomass in the Netherlands. *Ecological Economics, 69*(3), 579-591.

De Bruijn, Ten Heuvelhof, & In 't Veld. (2012). *Proces Management: over Procesontwerp en Besluitvorming* (4e ed.). Den Haag: BIM Media.

De Bruijn, H., & Herder, P. M. (2009). System and actor perspectives on sociotechnical systems. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, 39*(5), 981-992.

De Bruijn, H., & Heuvelhof, E. t. (2002). Policy analysis and decision making in a network: how to improve the quality of analysis and the impact on decision making. *Impact Assessment and Project Appraisal, 20*(4), 232-242.

De Coninck, H., Fischer, C., Newell, R. G., & Ueno, T. (2008). International technology-oriented agreements to address climate change. *Energy Policy, 36*(1), 335-356.

De Coninck, H., Flach, T., Curnow, P., Richardson, P., Anderson, J., Shackley, S., . . . Reiner, D. (2009). The acceptability of CO2 capture and storage (CCS) in Europe: An assessment of the key determining factors: Part 1. Scientific, technical and economic dimensions. *International Journal of Greenhouse Gas Control, 3*(3), 333-343.

Demailly, D., & Quirion, P. (2006). CO2 abatement, competitiveness and leakage in the European cement industry under the EU ETS: grandfathering versus output-based allocation. *Climate Policy, 6*(1), 93-113.

Douglas, M., & Wildavsky, A. (1983). *Risk and culture: An essay on the selection of technological and environmental dangers*: Univ of California Press.

Dröge, S., van Asselt, H., Brewer, T., Grubb, M., Ismer, R., Kameyama, Y., . . . Quirion, P. (2009). Tackling leakage in a world of unequal carbon prices. *Climate strategies, 1*.

Dryzek, J. S., & Berejikian, J. (1993). Reconstructive Democratic Theory. *American Political Science Review, 87*(01), 48-60.

Durning, D. (1999). The transition from traditional to postpositivist policy analysis: A role for Q-methodology. *Journal of Policy Analysis and Management, 18*(3), 389-410.

EC. (2011). Roadmap for moving to a competitive low carbon economy: European Commission.

EC. (2012). Connecting Europe. The energy infrastructure for tomorrow: European Comission.

EC. (2014). A Policy Framework for Climate and Energy in the Period from 2020 to 2030: European Commission

Edquist, C. (2001). *The Systems of Innovation Approach and Innovation Policy: An account of the state of the art.* Paper presented at the DRUID Conference, Aalborg.

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-actor Systems*. The Hague: LEMMA.

Feenstra, C., Mikunda, T., & Brunsting, S. (2010). What happened in Barendrecht. *Case study on the planned onshore carbon dioxide storage in Barendrecht, the Netherlands. Prepared by the Energy research Centre of the Netherlands (ECN) Project, 6*.

Fiorino, D. J. (1990). Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, technology & human values, 15*(2), 226-243.

Fischer, F., & Gottweis, H. (2012). *The argumentative turn revisited: public policy as communicative practice*: Duke University Press.

Forester, J. (1993). *The argumentative turn in policy analysis and planning*: Duke University Press.

Freeman, C. (1987). Technology policy and economic performance: lessons from Japan.

GCCSI. (2011). Accelerating the uptake of CCS: Industrial use of captured carbon dioxide: Global Carbon Capture and Storage Institute.

GCCSI. (2014). The Global Status of CCS. February 2014: Global Carbon Capture and Storage Institute.

Geels, F. (2005). The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technology Analysis & Strategic Management, 17*(4), 445-476.

Geels, F., & Kemp, R. (2007). Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. *Technology in Society, 29*(4), 441-455.

Gough, C., & Upham, P. (2011). Biomass energy with carbon capture and storage (BECCS or Bio-CCS). *Greenhouse Gases: Science and Technology, 1*(4), 324-334.

Goulder, L. H., & Parry, I. W. (2008). Instrument choice in environmental policy. *Review of Environmental Economics and Policy, 2*(2), 152-174.

Haan, A. d., & Heer, P. d. (2012). *Solving Complex Problems: Professional Group Decision-making Support in Highly Complex Situations* The Hague: Eleven International Publishing.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change, 74*(4), 413-432.

Hermans, L. (2005). *Actor analysis for water resources management: putting the promise into practice*: Eburon Uitgeverij BV.

Herzog, H. J. (2011). Scaling up carbon dioxide capture and storage: From megatons to gigatons. *Energy Economics, 33*(4), 597-604.

Hisschemöller, M. (2005). Participation as knowledge production and the limits of democracy *Democratization of Expertise?* (pp. 189-208): Springer.

Hisschemöller, M., & Hoppe, R. (1995). Coping with intractable controversies: the case for problem structuring in policy design and analysis. *Knowledge and Policy, 8*(4), 40-60.

Huijts, N., Midden, C. J., & Meijnders, A. L. (2007). Social acceptance of carbon dioxide storage. *Energy Policy, 35*(5), 2780-2789.

Hunold, C., & Young, I. M. (1998). Justice, democracy, and hazardous siting. *Political studies, 46*(1), 82-95.

IEA. (2013a). CO2 Pipeline Infrastructure: International Energy Agency.

IEA. (2013b). Technology Roadmap Carbon Capture and Storage: International Energy Agency.

IEA/UNIDO. (2011). Technology Roadmap Carbon Capture and Storage in Industrial Applications: International Energy Agency & United Nations Industrial Development Organization.

IEA/ZEP. (2011). The Costs of CO2 Storage. Post-demonstartion CCS in the EU.: International Energy Agency & European Technology Platform on Zero Emission Fossil Fuel Power Plants.

Ikeme, J. (2003). Equity, environmental justice and sustainability: incomplete approaches in climate change politics. *Global Environmental Change, 13*(3), 195-206.

Jann, W., & Wegrich, K. (2007). 4 Theories of the Policy Cycle. *Handbook of public policy analysis*, 43.

Johansson, D., Franck, P.-Å., & Berntsson, T. (2013). CO2 capture in oil refineries: Assessment of the capture avoidance costs associated with different heat supply options in a future energy market. *Energy Conversion and Management, 66*, 127-142.

Kessides, I. N. (2004). *Reforming infrastructure: Privatization, regulation, and competition*: World Bank Publications.

Kickert, W. J., Klijn, E.-H., & Koppenjan, J. F. M. (1997). *Managing complex networks: strategies for the public sector*: Sage.

Kingdon, J. W., & Thurber, J. A. (1984). *Agendas, alternatives, and public policies* (Vol. 45): Little, Brown Boston.

Koppenjan, J. F. M., & Klijn, E.-H. (2004). *Managing uncertainties in networks: a network approach to problem solving and decision making*: Psychology Press.

Krahé, M., Heidug, W., Ward, J., & Smale, R. (2013). From demonstration to deployment: An economic analysis of support policies for carbon capture and storage. *Energy Policy, 60*(0), 753-763.

Kuramochi, T., Ramírez, A., Turkenburg, W., & Faaij, A. (2012). Comparative assessment of CO2 capture technologies for carbon-intensive industrial processes. *Progress in energy and combustion science, 38*(1), 87-112.

Li, J., Tharakan, P., Macdonald, D., & Liang, X. (2013). Technological, economic and financial prospects of carbon dioxide capture in the cement industry. *Energy Policy, 61*, 1377-1387.

Lupion, M., & Herzog, H. J. (2013). NER300: Lessons learnt in attempting to secure CCS projects in Europe. *International Journal of Greenhouse Gas Control, 19*(0), 19-25.

Mace, M., Hendriks, C., & Coenraads, R. (2007). Regulatory challenges to the implementation of carbon capture and geological storage within the European Union under EU and international law. *International Journal of Greenhouse Gas Control, 1*(2), 253-260.

Meadowcroft, J. R., & Langhelle, O. (2009). *Caching the carbon*: Edward Elgar Publishing.

Menanteau, P. (2003). *Prices versus quantities : choosing policies for promoting the development of renewable energy*.

Mikunda, T., van Deurzen, J., Seebregts, A., Kerssemakers, K., Tetteroo, M., & Buit, L. (2011). Towards a CO2 infrastructure in North-Western Europe: Legalities, costs and organizational aspects. *Energy Procedia, 4*, 2409-2416.

Neele, F., Mikunda, T., Seebregts, A., Santen, S., van der Burgt, A., Stiff, S., & Hustad, C. (2013). A Roadmap Towards a European CO2 Transport Infrastructure. *Energy Procedia, 37*, 7774-7782.

Nicol, M. G. A., Stenhouse, M., Allinson, G., Berryman, K., Doody, B., Ho, M., . . . Webb, T. (2009). Opportunities for underground geological storage of CO2 in New Zealand-Report CCS-08/10-Risk assessment methodologies.

Oei, P.-Y., Mendelevitch, R., & Berlin, D. (2013). Development scenarios for a CO2 infrastructure network in Europe. *Draft paper for the Infrastructure Subgroup of the EMF, 28*.

ÖKO. (2012). Potenziale und Chancen der Technologie zur CO2-Abtrennung und–Ablagerung (CCS) für industrielle Prozessemissionen: Institut für angewandte Ökologie.

Olah, G. A., Goeppert, A., & Prakash, G. S. (2008). Chemical recycling of carbon dioxide to methanol and dimethyl ether: from greenhouse gas to renewable, environmentally carbon neutral fuels and synthetic hydrocarbons. *The Journal of organic chemistry, 74*(2), 487-498.

Oltra, C., Sala, R., Solà, R., Di Masso, M., & Rowe, G. (2010). Lay perceptions of carbon capture and storage technology. *International Journal of Greenhouse Gas Control, 4*(4), 698-706.

Pearson, I., & Whirisky, K. (2013). Market Incentives Report: Driving CO2 Capture and Storage in the EU. New Policies, New Perspectives.

Pearson, R. J., Eisaman, M. D., Turner, J. W., Edwards, P. P., Jiang, Z., Kuznetsov, V. L., . . . Taylor, S. G. (2012). Energy Storage via Carbon-Neutral Fuels Made From CO, Water, and Renewable Energy. *Proceedings of the IEEE, 100*(2), 440-460.

Radgen, P., Kutter, S., & Kruhl, J. (2009). The legal and political framework for CCS and its implications for a European Utility. *Energy Procedia, 1*(1), 4601-4608.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences, 4*(2), 155-169.

Rochon, E., Kuper, J., Bjureby, E., Johnston, P., Oakleym, R., Santillo, D., . . . Goerne, G. v. (2008). False hope: why carbon capture and storage won't save the climate. *False hope: why carbon capture and storage won't save the climate*.

Sabatier, P. A., & Jenkins-Smith, H. C. (1993). Policy change and learning: An advocacy coalition approach.

Sanders, M., Fuss, S., & Engelen, P.-J. (2013). Mobilizing private funds for carbon capture and storage: An exploratory field study in the Netherlands. *International Journal of Greenhouse Gas Control, 19*, 595-605.

SCCS. (2013a). Briefing: CCS for industrial Sources of CO2 in Europe: Scottish Carbon Capture and Storage.

SCCS. (2013b). Tackling industry's carbon emissions: drivers and barriers to CO2 capture in Scotland *Workshops for Industrial Emitters*: Scottish Carbon Capture and Storage.

Schusler, T. M., Decker, D. J., & Pfeffer, M. J. (2003). Social learning for collaborative natural resource management. *Society & Natural Resources, 16*(4), 309-326.

Scott, V. (2013). What can we expect from Europe's carbon capture and storage demonstrations? *Energy Policy, 54*, 66-71. doi: DOI 10.1016/j.enpol.2012.11.026

Scrase, J. I., & Watson, J. (2009). Strategies for the deployment of CCS technologies in the UK: a critical review. *Energy Procedia, 1*(1), 4535-4542.

Shackley, S., Reiner, D., Upham, P., de Coninck, H., Sigurthorsson, G., & Anderson, J. (2009). The acceptability of CO2 capture and storage (CCS) in Europe: An assessment of the key determining factors: Part 2. The social acceptability of CCS and the wider impacts and repercussions of its implementation. *International Journal of Greenhouse Gas Control, 3*(3), 344-356.

Simon, H. A. (1991). Bounded rationality and organizational learning. *Organization science, 2*(1), 125-134.

Singleton, G., Herzog, H., & Ansolabehere, S. (2009). Public risk perspectives on the geologic storage of carbon dioxide. *International Journal of Greenhouse Gas Control, 3*(1), 100-107.

Singleton, G. R. (2007). *Geologic storage of carbon dioxide: risk analyses and implications for public acceptance.* Massachusetts Institute of Technology.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., . . . Miller, H. L. (2007). IPCC, 2007: Climate change 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. *SD Solomon (Ed.)*.

Spahn, A., & Taebi, B. (2009). *Sustainability, ethics and CCS.* Paper presented at the Workshop on the coherence of non technical aspects of CCS and monitoring, Amsterdam, The Netherlands.

Stainton Rogers, R. (1995). Q methodology. *Rethinking methods in psychology*, 178-192.

Stephens, J. C. (2006). Growing interest in carbon capture and storage(CCS) for climate change mitigation. *Sustainability: Science Practice and Policy, 2*(2), 4-13.

Stephens, J. C., & Jiusto, S. (2010). Assessing innovation in emerging energy technologies: socio-technical dynamics of carbon capture and storage (CCS) and enhanced geothermal systems (EGS) in the USA. *Energy Policy, 38*(4), 2020-2031.

Stephenson, M. H. (2013). *Returning Carbon to Nature: Coal, Carbon Capture, and Storage*: Newnes.

Suurs, R. A. (2009). Motors of sustainable innovation: Towards a theory on the dynamics of technological innovation systems.

Teir, S., Tsupari, E., Arasto, A., Koljonen, T., Kärki, J., Lehtilä, A., . . . Nieminen, M. (2011). Prospects for application of CCS in Finland. *Energy Procedia, 4*, 6174-6181.

Teisman, G. R. (2000). Models For Research into Decision-MakingProcesses: On Phases, Streams and Decision-Making Rounds. *Public administration, 78*(4), 937-956.

Thomas, D. B., & Baas, L. R. (1992). The issue of generalization in Q methodology:"Reliable schematics" revisited. *Operant Subjectivity, 16*(1), 18-36.

Torvanger, A., & Meadowcroft, J. (2011). The political economy of technology support: Making decisions about carbon capture and storage and low carbon energy technologies. *Global Environmental Change, 21*(2), 303-312.

Tzimas, E., Georgakaki, A., Cortes, C. G., & Peteves, S. (2005). Enhanced oil recovery using carbon dioxide in the European energy system. *Report EUR, 21895*.

Van Alphen, K., Van Ruijven, J., Kasa, S., Hekkert, M., & Turkenburg, W. (2009). The performance of the Norwegian carbon dioxide, capture and storage innovation system. *Energy Policy, 37*(1), 43-55.

Van Exel, J., & de Graaf, G. (2005). Q methodology: A sneak preview.

van Straelen, J., Geuzebroek, F., Goodchild, N., Protopapas, G., & Mahony, L. (2010). CO2 capture for refineries, a practical approach. *International Journal of Greenhouse Gas Control, 4*(2), 316-320.

Volkart, K., Bauer, C., & Boulet, C. (2013). Life cycle assessment of carbon capture and storage in power generation and industry in Europe. *International Journal of Greenhouse Gas Control, 16*, 91-106.

Von Stechow, C., Watson, J., & Praetorius, B. (2011). Policy incentives for carbon capture and storage technologies in Europe: A qualitative multi-criteria analysis. *Global Environmental Change, 21*(2), 346-357.

Watson, J., Kern, F., & Markusson, N. (2014). Resolving or managing uncertainties for carbon capture and storage: lessons from historical analogues. *Technological Forecasting and Social Change, 81*, 192-204.

Watts, S., & Stenner, P. (2005). Doing Q methodology: theory, method and interpretation. *Qualitative Research in Psychology, 2*(1), 67-91.

Webler, T. (1995). *"Right" discourse in citizen participation: an evaluative yardstick*: Springer.

Webler, T., Danielson, S., & Tuler, S. (2009). Using Q method to reveal social perspectives in environmental research. *Greenfield MA: Social and Environmental Research Institute*, 54.

Wong-Parodi, G., Ray, I., & Farrell, A. E. (2008). Environmental non-government organizations' perceptions of geologic sequestration. *Environmental Research Letters, 3*(2), 024007.

ZEP. (2011). The Costs of CO2 transport. Post-demonstration CCS in the EU: European Technology Platform on Zero Emission Fossil Fuel Power Plants.

ZEP. (2013a). CO2 Capture and Storage in Energy Intensive Industries: An indispensable road to an EU low-carbon economy: European Technology Platform on Zero Emission Fossil Fuel Power Plants.

ZEP. (2013b). CO2 Capture and Use: the potential to reduce CO2 emissions and accelarate CCS deployment n Europe: European Technology Platform on Zero Emission Fossil Fuel Power Plants.

APPENDIX 1: LIST OF INTERVIEWEES CONCOURSE IDENTIFICATION

Tom Mikunda
Researcher CCS
Energy Centrum Nederland (ECN)

Heinz Bergmann
Managing Director
Rheinisch-Westfälisches Elektrizitätswerk (RWE)

Jonas Helseth
Director Europe
Bellona

Peter Radgen
Technology Area Manager CCS
E.ON

Javier Alonso
Manager
Natural Gas Fenosa

Nelly Castilla Garcia
Delegate
Ciudad de la Energia (CIUDEN)

Tim Bertels
Manager Global CCS Portfolio
Shell

John Chamberlain
Technological Project Manager
Natural Gas Fenosa

Nils Røkke
Vice President Climate
Stiftelsen for Industriell og Teknisk Forskning (SINTEF)

Andrew Purvis
General Manager Europe, Middle East & Africa
Global Carbon Capture and storage Institute (GCCSI)

Graeme Sweeney

Chairman

European Technology Platform on Zero Emission Fossil Fuel Power Plants (ZEP)

Richard van der Sanden

Director

Dutch Institute for Fundamental Energy Research (DIFFER)

APPENDIX 2: INTERVIEW PROTOCOL CONCOURSE DEFINITION

1. Send an email
    a. Introduce myself
    b. Introduce what I am working on
    c. Explain what I would like to ask
2. Call for appointment
3. Interview
    a. Introduction

        Graduation internship about CCS in high emission industries at Triarii, Zero Emissions Platform Secretariat

        Student Delft University of Technology

        6 months
    b. CCS in EnII
        i. Who are the players in CCS in EnII?
            1. What industries?
            2. Key players in industry?
        ii. What do you think about the industry's interest in CCS?
        iii. What are the main topics for the industry when it comes to CCS?
            1. R & D topics?
            2. EU legislation?
            3. storage and infrastructure?
            4. carbon leakage?
            5. societal case: employment?
            6. CCS in industrial clusters?
            7. to give direction to H2020?
            8. pilots and demos for industrial CCS?
        iv. What policies can incentivize the EnII to do CCS?
        v. What could be a development that would convince the industry to do CCS?
        vi. What key events do you see in the future of CCS?
    c. Research topic
        i. What do you think would be a relevant topic with relation to industrial CCS?
        ii. Do you know of any current knowledge gaps?

APPENDIX 3: Q SAMPLE

	STATEMENT
1	CCS in EnIIs is indispensable in meeting the EU's emission reduction targets.
2	The CO2 utilization (for example in carbon-neutral fuels, construction materials or enhanced oil recovery) offers great opportunities for CCS development.
3	EnIIs have a moral obligation to invest in low-carbon technologies such as CCS.
4	People in EnIIs have limited knowledge of CCS.
5	EnIIs are not investing in CCS because of their short term orientation.
6	The negative political attitude towards CCS in EnII is a key barrier for CCS in EnII.
7	Technology for CCS in EnIIs will not be ready in time to mitigate climate change.
8	The European Commission has to be more outspoken in favor if CCS in EnIIs.
9	New CCS demonstration projects in EnIIs should be one of the main priorities.
10	The low price of allowances in the EU ETS is one of the main barriers for the development of CCS in EnIIs.
11	CCS decreases the general awareness of the problem of CO2 emissions.
12	CCS in EnIIs will always remain too costly.
13	CCS in EnIIs will make consumer prices unacceptably high.
14	Because financers have limited knowledge of CCS there is capital underprovision for CCS projects.
15	The deployment of CCS in EnIIs creates unacceptable environmental risks.
16	The uncertainty in ETS allowance prices is one of the key barriers to CCS development.
17	More investments in R&D for CCS in EnIIs can significantly decrease costs.
18	Because EnIIs are facing international competition, emission reduction is very difficult for them.
19	EnIIs do not like to speak about CCS in public.
20	Investments in CCS decreases investments in renewables, so governments should not subsidize CCS.
21	CCS should not be part of an emissions reduction strategy of the EnIIs since it increases the use of fossil fuels.
22	The lower capture costs in EnIIs compared to the power industry creates opportunities for early deployment of CCS in EnIIs.
23	It would help CCS in EnII if more environmental NGOs would be in favor of CCS in EnIIs.
24	The uncertainty about what the costs for CCS will become, is one of the main barriers for CCS in EnIIs.
25	Instead of CCS in EnIIs we should drastically decrease our production.
26	The EnIIs will not be able to pay for the development of a CO2 transport and storage infrastructure.
27	International agreement on emission reduction targets will be reached.

28 Public resistance is one of the main problems with CCS.

29 The EnIIs and the power industry have many common interests when it comes to CCS and should work together.

30 CCS will contribute significantly to maintaining employment in the EU's EnIIs.

31 Carbon border adjustment should be implemented in order to prevent carbon leakage of EnIIs.

APPENDIX 4: INTERVIEW PROTOCOL Q INTERVIEW

1. Introduction
    a. Jacob de Jongh, graduate student Engineering and policy Analysis at Delft University of technology. Graduate intern at zero emissions platform.
    b. I work at the secretariat of ZEP which enables me to do my research to CCS in energy intensive industries. The research will enable me to graduate and possibly a small contribution to CCS in EII.
2. Research:
    a. Objective is to improve governance of CCS in EIIs in the EU.
    b. Many perceptions on CCS in EnII amongst stakeholders (industry, NGO, government). Goal is to systematically map the different perspectives on CCS in EnII.
    c. Purpose of the methodology: identify different perceptions of stakeholders on CCS in EIIs in the EU.
3. Information usage
    a. There will be made no reference to the information provided in these interview without your explicit permission.
    b. I will make an interview report in which you can make changes when you disagree.
    c. Can I record the interview?
4. Formal questions
    a. What is your name?
    b. What organization do you represent?
    c. What is your function within the organization?
    d. What are your tasks and responsibilities?
5. Questions about CCS in EIIs
    a. What are your ideas about CCS in EIIs?
6. Q sort instruction
    a. Please rank the 47 statements from most disagree (left) to most agree (right)
    b. The abbreviations used in the statements can be found on the instruction paper
    c. The vertical axis has no meaning
    d. The middle column is not necessary the zero point
    e. Please think out loud when sorting the statements
    f. You can start by making three piles
7. After sort
    a. Why have you put these statements at the extremes?
    b. Do you miss any statements or topics for CCS in EIIs?
    c. Do you think some statements have no meaning for CCS in EIIs?
    d. What do you think could be strategies to bring CCS in EIIs further?

8. Ending
    a. Any other comments about CCS in EIIs of this research
    b. Thank you for your participation
    c. I will send you the final report

APPENDIX 5: P SAMPLE

Jason Anderson
Head EU Climate & Energy Policy
World Wildlife Fund

Giovanni Cinti
Technology Department Manager
Italcementi

Chris Davies
Member of Parliament - Spokesperson Environment Liberal Democrats
European Parliament

Lamberto Eldering
Principal Consultant CCS
Statoil

Aurélien Genty
Policy Officer Sustainable Industrial Policy & Construction
European Commission - Directorate-General Enterprise & Industry

Jonas Helseth
Director Europe
Bellona

Alexandr Jevsejenko
Policy Officer for Low-Carbon Technologies
European Commission – Directorate-General Climate Action

Vassilios Kougionas
Research Program Officer
European Commission – Directorate-General Research & Innovation

Wilfried Maas
CO2 Theme Leader
Shell

Rob van der Meer
Director EU Public Affairs
Heidelberg Cement

Tim Peeters

Department Manager Iron Making

Tata Steel

Juha Ylimaunu

Senior Vice President Environment, Health & Safety

Outokumpu

Christina Kandziora

Task Manager CCS

Linde Gas and Engineering

Tom Mikunda

Researcher CCS

ECN

APPENDIX 6: CORRELATION MATRIX Q SORTS

SORT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	51	18	26	60	55	56	9	25	2	-5	53	45	47
2	51	100	30	23	61	36	53	47	25	-3	40	74	65	67
3	18	30	100	7	50	6	33	25	-3	15	14	41	42	39
4	26	23	7	100	25	33	27	3	47	25	30	52	35	28
5	60	61	50	25	100	30	50	23	23	4	29	67	61	55
6	55	36	6	33	30	100	28	3	-4	28	-2	48	18	32
7	56	53	33	27	50	28	100	18	24	1	27	38	45	43
8	9	47	25	3	23	3	18	100	-3	12	40	31	50	35
9	25	25	-3	47	23	-4	24	-3	100	4	52	37	55	28
10	2	-3	15	25	4	28	1	12	4	100	30	15	15	4
11	-5	40	14	30	29	-2	27	40	52	30	100	34	66	35
12	53	74	41	52	67	48	38	31	37	15	34	100	70	59
13	45	65	42	35	61	18	45	50	55	15	66	70	100	64
14	47	67	39	28	55	32	43	35	28	4	35	59	64	100

APPENDIX 7: Q SORTS FACTOR LOADINGS

Q SORT	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
1	-0.1037	0.6385*	0.3598	0.1694
2	-0.0829	0.4155	0.3711	0.6112*
3	0.0990	0.1503	0.0918	0.4779*
4	0.1143	0.5447*	0.4220	-0.1462
5	0.0451	0.4682	0.3429	0.4674
6	0.2886	0.6773*	0.0302	0.0252
7	0.1236	0.3371	0.3592	0.2893
8	0.0358	0.0209	0.0985	0.6387*
9	-0.0846	0.0027	0.7984*	-0.0203
10	0.5478*	0.1288	0.0217	0.0244
11	0.3125	-0.0940	0.5980*	0.3334
12	0.1421	0.6220*	0.4096	0.4221
13	0.1548	0.2253	0.6805*	0.5090
14	0.0418	0.3815	0.3460	0.5250*
EXPLAINED VARIANCE	4%	16%	18%	16%

Asterisk * indicates significant or defining Q sorts

APPENDIX 8: FACTOR ARRAYS

	STATEMENT	F1	F2	F3	F4
1	CCS in EnIIs is indispensable in meeting the EU's emission reduction targets.	0	4	3	2
2	The CO2 utilization (for example in carbon-neutral fuels, construction materials or enhanced oil recovery) offers great opportunities for CCS development.	0	0	0	1
3	EnIIs have a moral obligation to invest in low-carbon technologies such as CCS.	2	2	2	-3
4	People in EnIIs have limited knowledge of CCS.	-1	1	0	-2
5	EnIIs are not investing in CCS because of their short term orientation.	-3	1	0	0
6	The negative political attitude towards CCS in EnII is a key barrier for CCS in EnII.	-1	-1	0	-2
7	Technology for CCS in EnIIs will not be ready in time to mitigate climate change.	-1	-2	-4	-4
8	The European Commission has to be more outspoken in favor if CCS in EnIIs.	-1	2	-1	0
9	New CCS demonstration projects in EnIIs should be one of the main priorities.	2	3	1	1
10	The low price of allowances in the EU ETS is one of the main barriers for the development of CCS in EnIIs.	1	0	4	4
11	CCS decreases the general awareness of the problem of CO2 emissions.	-1	-3	-3	-1
12	CCS in EnIIs will always remain too costly.	0	-2	-2	-1
13	CCS in EnIIs will make consumer prices unacceptably high.	3	-4	0	-1
14	Because financers have limited knowledge of CCS there is capital underprovision for CCS projects.	-1	0	-1	-1
15	The deployment of CCS in EnIIs creates unacceptable environmental risks.	1	-2	-2	-3
16	The uncertainty in ETS allowance prices is one of the key barriers to CCS development.	1	-1	3	2
17	More investments in R&D for CCS in EnIIs can significantly decrease costs.	1	2	1	2
18	Because EnIIs are facing international competition, emission reduction is very difficult for them.	3	3	-2	3
19	EnIIs do not like to speak about CCS in public.	2	-1	0	0
20	Investments in CCS decreases investments in renewables, so governments should not subsidize CCS.	-1	-2	1	-2
21	CCS should not be part of an emissions reduction strategy of the EnIIs since it increases the use of fossil fuels.	0	-1	-1	-1
22	The lower capture costs in EnIIs compared to the power industry creates opportunities for early deployment of CCS in EnIIs.	-3	0	2	1
23	It would help CCS in EnII if more environmental NGOs would be in favor of CCS in EnIIs.	-1	1	-1	0
24	The uncertainty about what the costs for CCS will become, is one of the main barriers for CCS in EnIIs.	1	1	2	0
25	Instead of CCS in EnIIs we should drastically decrease our production.	-4	-3	-3	-2

26	The EnIIs will not be able to pay for the development of a CO2 transport and storage infrastructure.	1	0	2	0
27	International agreement on emission reduction targets will be reached.	-2	0	-2	0
28	Public resistance is one of the main problems with CCS.	-1	-1	0	1
29	The EnIIs and the power industry have many common interests when it comes to CCS and should work together.	-2	2	1	3
30	CCS will contribute significantly to maintaining employment in the EU's EnIIs.	0	1	-1	2
31	Carbon border adjustment should be implemented in order to prevent carbon leakage of EnIIs.	-2	0	1	1

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