Unravelling the Contested Nature of Carbon Capture and Storage

Sander van Egmond

This research has been carried out in the context of the CATO-2-programme. CATO-2 is the Dutch national research programme on CO_2 Capture and Storage. The programme is financially supported by the Dutch government (Ministry of Economic Affairs) and the CATO-2 consortium parties.

ISBN: 978-90-393-6573-1

Cover: During one of the CATO conferences I had an interesting conversation with Prof. dr. Krijn de Jong who compared CCS with either a multi-headed dragon from the perspective of opponents or with a multi cleaning towel for proponents (de Jong, 2010). The latter I transformed into a Swiss pocket knife or multi tool on which was the inspiration for the cover. De Jong used this metaphor as CCS consists of hundreds of different chains, all having their own advantages and disadvantages. Later I used this comparison to explain to my daughter that your view is determined by the way you look at things. She ran upstairs to get the picture of the famous illusion by Hill (1915). Does it depict a beautiful young girl or an old woman?

Unravelling the Contested Nature of Carbon Capture and Storage

Analyse van het debat over CO_2 afvang en opslag

(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. G.J. van der Zwaan, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op vrijdag 3 juni 2016 des middags te 12:45 uur

door

Sander van Egmond

geboren op 22 juni 1973 te Utrecht

Promotor: Prof.dr. M.P. Hekkert

Copromotor: Dr. J.C.M. Farla

Contents

1. Introduction

1.1. Technology and society

Technology is an essential part of modern life. Technological development brought increased economic welfare, as production and availability of all kind of consumables grew enormously in the last century. The introduction of household appliances gave us more spare time, our life expectancy has increased considerably due to the development of new medical treatments and technologies, and nowadays we can easily travel to other continents and have live communication with our families and colleagues at the other side of the world. Thus, many will argue that technology has improved the quality of our day to day life.

However, the development of new technologies also sparks concerns in society. For instance, in the beginning of the 19th-century English textile workers protested against the implementation of labour extensive technologies. These so called Luddites feared that industrial revolution would replace their jobs (Schot, 2003). Similarly the advantages and drawbacks of (modern) robots are currently under debate in society (Rathenau Instituut, 2012). The development of nuclear weapons resulted in mass demonstrations in the second part of the 20th century.

In the sixties and seventies of the 20th century concerns about the depletion of the earth's resources and harmful side effects to the environment due to industrialisation started. The Club of Rome's report 'Limits to Growth' warned that a continued growth of the economy and population would lead to an overshoot and collapse of the global system (Meadows et al., 1972). These concerns are related to many different technologies, maybe even to technology development in general, although concerns about a specific technology are possible as well. Examples of the latter are the risk related to nuclear power plants or the visual impact of wind turbines. Many studies have analysed underlying motives that lead to acceptance or rejection of a new technology.

This thesis focuses on the societal evaluation of a specific technology, Carbon Capture and Storage (CCS), which is a technology that captures CO_2 from the exhaust gases of power plants or large industrial facilities. CO_2 is subsequently transported to a storage location and then stored in the deep subsurface in depleted gas fields or aquifers. Many scientists and policy makers consider CCS necessary to mitigate climate change (e.g. IEA, 2013b). However, the actual deployment is slow, and the technology is contested by society. To increase the speed of implementation more incentives are required. By understanding the discourse on CCS, one can get an idea whether society is willing to provide these incentives.

1.2. Perceptions of technology versus environment

Before introducing the CCS technology I first give a short introduction on different views on the relation between technology and environment. As I will show some perceive technology development as a cause for environmental problems, whereas others consider technology as the solution. Furthermore, the existence and seriousness of environmental problems is perceived differently.

In the sixties and seventies of the 20th century the environmental debate started. The Club of Rome's report 'Limits to Growth' warned that a continued growth of the economy and population would lead to an overshoot and collapse of the global system (Meadows et al., 1972). Hardin (1968) also warned against the depletion of the earth's resources and the collapse of ecosystems, but with a different focus. He pointed out that – based on an evolutionary standpoint – a rational individual will maximise its own benefits even if this is against the advantage of the society as a whole. A classic example is the fish stock in the sea, which theoretically belongs to us all. Still, the economical yield is not evenly distributed when comparing for instance large multinationals and local fishermen. Hardin refers to these kinds of resources as 'commons'. The atmosphere can also be regarded as a 'common'. An individual, who pollutes the atmosphere to maximise utility does not suffer the negative consequences, but society as a whole will. According to Hardin this 'tragedy of the commons' is caused by the use of technology and cannot be solved by technology.

In contrary to these 'doomsday thinkers' (Dryzek and Schlosberg, 2005) others deny a global environmental crisis and see technology development as an important means to preclude such a crisis. Simon and Kahn (1984) for example stated that deforestation on a global scale is not worrying, and that mineral resources are becoming less scarce rather than more scarce due to new extracting technologies. They admitted that local problems may arise, but argued that the cause of these problems had more to do with local mismanagement than global issues. Lomborg (2001) showed that the pollution by sulphur dioxide in London increased from 1600 onwards until 1900, but afterwards decreased enormously. He stated that the air is currently cleaner than before 1600. This observation is in accordance with the concept of the environmental Kuznets curves. Based on this concept pollution shows an inverted U-shape when plotted against economic wealth, as pollution will grow at the introduction of new technologies, but will decrease again when technologies mature (Stern et al., 1996).

Values linked to the environmental and technology debate
In summary, there are different perceptions on the role of technology, the seriousness of environmental problems and the relation between technology and environmental problems. Rittel and Weber (1973) refer to these complex societal problems as 'wicked' problems, in contrary to the classic 'tame' problems in the natural sciences, in which theoretically problem definition and potential solutions are more univocal. The resolution of a 'wicked problem' depends on one's value, as there is not one indisputable solution. Moreover, Rittel and Weber (1973) consider that the formulation of these unstructured problems is problematic in itself, as one should already have knowledge on all conceivable solutions (Rittel and Webber, 1973). Besides the importance of values, Van Bueren et al. (2003) also point at the institutional level of the actor, as problems and solutions from a local point of view may differ significantly from an (inter)national perspective. Moreover, it is possible that different perceptions on a problem may lead to the same solution, even though the underlying motivation is different.

I illustrate the importance of values on the perception of environmental issues with two examples that have provoked strong different views. First, social ecologists see the hierarchy in society as the underlying problem for environmental problems (Bookchin, 1990). For example, they refer to the higher position of men versus women, of owners above labourers, and of humans above nature. In accordance with the social ecologists, the deep ecologists also advocate for a change in society in order to solve environmental problems. They support strong local autonomy, and a better distribution of welfare (Naess, 1973). In 'small is beautiful', Schumacher (1973) pleaded for a less greedy society and a return to a small and more human scale of activities. He also stated that the welfare of a society cannot be measured by the Gross National Product and argued for another economic system (Schumacher, 1973). These groups thus consider the 'environmental problem' as a symptom of the over-consumption in current society due to the globalisation and hierarchy in society.

A second example is the notion of Rand (1975). In her bestseller 'Atlas shrugged' she argued that the proper moral purpose of one's life is the pursuit of one's own happiness (Rand, 1975). In her view the laissez-faire capitalism is the only system that is coherent with this morality. As such, there is no place for government policy for protection of the environment or the 'commons'. Van Soest (2014) suggests that this ideology may explain why right-wing Americans deny climate change and reject policy to prevent climate change. He argues that supporters of this ideology have such a strong believe in their system that they discard any negative impacts that the system might generate. And even if climate change may occur, than the cure (government policy) would be worse than the disease (climate change). Van Soest (2014) illustrates the latter with a phrase used by this group that 'environmentalists are like watermelons: green on the outside but red (socialist) on the inside'.

From the above I assume that different values also influence the debate on CCS.

1.3. Approaches to evaluate energy technologies

In order to understand what role science may play in the evaluation of CCS, I describe some commonly used scientific approaches to evaluate energy technologies in this section. This overview is limited to energy technologies, because CCS is applied mostly at technologies that convert energy, for example from natural gas into electricity. Furthermore, I label CCS as an environmental technology because essentially CCS is used to prevent carbon dioxide from entering the atmosphere. I therefore give special attention to the assessment of potential environmental impact of energy technologies.

A distinction is made between studies that start from a techno-economic approach and studies with a social science point of view. The techno-economic approaches to learn about new technologies are rooted in a positivist research tradition. These studies help us to understand the new technology by presenting 'factual' data on costs, energy consumption and other characteristics of the new technology. Decision makers in government and industry often rely on such studies because it helps them to choose between different (renewable) energy technologies.

Part of the social science studies also rely on quantifiable facts, for instance about the public acceptance of new technologies. On the other hand, part of these social science studies is rooted in a constructionist research tradition. Examples are constructive technology assessment studies and risk analysis studies. This approach does not necessarily lead to one optimal answer to complex questions about which technology would serve society best, as this will also depend on the view point of different actors in society. Policymakers that have to make technological choices often feel less well served by this type of studies. Against this background it is interesting to give a short overview of what scientists do in order to help societal decision making on new technologies.

1.3.1. Techno-economic approach

The techno-economic approaches provide data that help decision makers to choose between new (energy) technologies.

Assessing the potential of a technology
The first approach I describe is the determination of the potential of a technology. This is often presented in quantitative units, such as the maximum reduction of CO_2, costs or energy use when a technology is fully implemented. To analyse the possible contribution of a technology, first a theoretical maximum potential is calculated. Afterwards, a more realistic potential is obtained by applying certain criteria. The first criterion is technical limitations, which result in a technical potential. This is further narrowed by social constraints like economic boundary conditions. For example, the theoretical potential of onshore wind energy is 290% compared to the world's yearly energy consumption. When technical and geographical limitations are applied a more realistic potential is calculated, which is further decreased when social constraints are taken into account (Hoogwijk et al., 2004). It is important to note that these techno-economic potentials are not fixed, as for example technology can be improved and costs reduced.

Technology comparison
Comparing the performance of technologies is a method to determine the strong and weak points of a new technology. An obvious method is to compare the economic performance of technologies. For instance, this type of analysis shows that the cost of electricity generated from fossil fuelled power plants is often lower compared to renewable energy technologies (Transparent Cost Database, 2015).

It is also possible to compare the environmental performance of technologies. In the climate debate the CO_2 emission per kWh is for example often used to compare (low) carbon technologies. The direct CO_2 emission of gas-fired power plants is on average 370 gram CO_2/kWh, whereas the emissions of coal-fired power plants are approximately twice that value (IPCC, 2014). The direct emissions of solar and wind energy are zero. A more comprehensive approach is to include all emissions related to an energy source, and not only the direct emissions. Indirect emissions occur for example during the production of wind turbines and the transport of coal. A Life Cycle Analysis (LCA) takes all environmental impacts during production, use and dismissal of the product into account (Bhat and Prakash, 2009; Pehnt, 2006). These environmental emissions harm the environment, but these 'costs' are rarely allocated directly to the producer of these emissions. It is therefore advocated that the external costs should be taken into account in economical comparison (Krewitt, 2002).

Scenarios and roadmaps

The knowledge of the potential and characteristics of a technology serves as an input for scenarios and roadmaps. Scenarios help decision makers by showing the consequences of their decisions, or the absence of such decisions. There are many different types of scenarios that can be characterised based on their goal, method, content and characteristics (van Notten et al., 2003). An important starting point is the vantage point from which a scenario is developed. Forecast scenarios take the current situation as the basis for scanning future developments and often have a more explorative character. By contrast, backcasting scenarios define the paths that are necessary to reach future goals. These scenarios can have a more prescriptive character and help to guide decision making. The World Energy Scenario is an example of forecasting, and explores possible future developments based on two variants (WEC, 2013). First, 'The Jazz variant' gives priority to achieving access and affordable energy through economic growth, whereas 'The Symphony variant' focuses on achieving environmental sustainability through internationally coordinated policies and practices. Both scenarios, but particularly 'The Jazz variant', show that fossil fuels will still play a crucial role in 2050. The '100% renewable energy scenario' developed for WWF is an example of backcasting, in which a path towards a fully renewable energy system in 2050 was developed (WWF, 2011).

Roadmaps identify the necessary concrete steps that need to be taken in order to reach a future goal. An example is the IEA study on solar energy (IEA, 2014a). In the roadmap approach barriers that need to be overcome in order to reach a specific goal are identified. Additionally, recommendations are proposed to deal with the problems. Strengthening of the international R&D, and streamlining of the permit procedures are examples of recommendations that are necessary to achieve the vision that solar energy will produce 16% of the global electricity in 2050 (IEA, 2014a).

1.3.2. Social science approach

Analyses with a techno-economic perspective may identify the possibilities of new technologies, but often do not address the question whether the society is willing to accept these technologies. The social sciences study how technological development is influenced by social and economic processes including governance issues and how the societal debate around technologies is constructed.

Much work is done to measure the attitude from the public towards specific technologies. It is important to notice that there is a difference between the attitude of the general public and the population near a site where the technology is actually applied. Projects can generate local benefits, like employment, as well as local drawbacks like risks and inconvenience. Therefore, the considerations of the local population may differ from the attitude of the general public. Besides measuring the attitude of the public, the factors that influence this acceptance have been thoroughly examined. An understanding of these factors may give opportunities for implementation and communication strategies.

Acceptance of the general public
Gupta et al. (2012) made an overview on the determinants of public acceptance of ten controversial technologies, including genetic modification, nanotechnology, hydrogen power and nuclear power. The six factors that were investigated most in literature were perceived risks, trust, perceived benefits, knowledge, individual differences and attitude. The number and type of determinants of acceptance varied between technologies. For example, literature on cloning showed a focus on ethics and expert versus lay knowledge as main factors for understanding public attitude while acceptance of nuclear technology was among others associated with values, role of societal actors, perceived risks, general attitude, and perceived costs.

Another literature overview (Huijts et al., 2012) analysed the psychological factors for renewable energy acceptance and found comparable factors to the six most important determinants that Gupta et al. (2012) identified. In the overview by Huijts et al. (2012) also social and personal norms as well as fairness were determined as important factors for acceptance. The public considered a project more fair when benefits and negative impacts were evenly distributed and the public was involved in the decision making of the project.

One of the most analysed factors regarding public acceptance is risk. There are two types of risk analysis, based on analytical measurements or based on perceptions, respectively (Slovic et al., 2004). In the analytical method probability and impacts are multiplied to define the calculated risk. These studies are typically performed by engineers that for example calculate the expected number of casualties over a defined time period due to a calamity in an industrial installation. The other method is the usual way to deal with risks in normal day life. It relies on images, associations, experience and emotions (Slovic et al., 2004). This evaluation method addresses the perceived risk. It helped humans to survive, by assessing dangers long before probability theory was developed.

For many decades communication strategies to influence perceived risk have been developed. Fischhoff (1995) gave an overview of the development of such strategies. This started from a technical perspective that focused on the correct risk numbers. Later it was realised that this approach was insufficient, and proper communication to the public was required. Next, strategies were transferred from one way communication into an approach in which the population was involved in the projects in a two way communication. It is now clear that factors like trust, fairness, individual differences, and perceived benefits influence both perceived risks and public acceptance of a technology (Fischhoff et al., 1978; Krütli et al., 2010; RIVM, 2003; Whitfield et al., 2009).

Acceptance of the local population

As mentioned before, when a local population is confronted with projects like waste dump sites, wind turbine parks, or airports in their neighbourhood their attitude towards a technology as well as to the proposed project may change. The usual term for this phenomenon is NIMBY (Not In My Back Yard). There has been a lot of discussion on the concept of NIMBY, because the name suggests that local opposition is strictly driven by self-interest. However, this is an oversimplification as other factors may explain local opposition as well (Burningham, 2000; Devine-Wright, 2005; Wolsink, 2007). For example, a person who rejects the principle of nuclear energy will reject any nuclear power plants, not only the one that is planned in the neighbourhood. This person is therefore not only driven by self-interest to protect the own back yard.

Many studies have been performed to understand the motives of the local public and propose strategies to deal with local opposition. Dear (1992) mentioned for example the perceived threat to decreased property value, personal security (risk) and potential decline of the neighbourhood quality as important factors to explain local opposition. Factors that explain local resistance to wind turbine parks are among many others visual impact, ownership, previous experience and knowledge, public participation and consultation (Devine-Wright, 2005; Jobert et al., 2007; Toke et al., 2008). This knowledge enables project developers to develop better communication and implementation strategies.

Technology Assessment (TA)
The studies on the acceptance of a technology identify factors that influence the acceptance of technology. However this type of research does not answer the question whether these factors, like risks, occur when a new technology is implemented. Since the 1950's public interest has grown concerning the negative impact of technology, which resulted in a new type of studies referred to as Technology Assessment (TA). Originally, TA emphasised the negative consequences of new technologies via neutral fact finding (Van Den Ende et al., 1998). Technology assessment was defined as 'a class of policy studies, which systematically examine the effects on society that may occur when a technology is introduced, extended or modified. It emphasises those consequences that are unintended, indirect or delayed' (Coates, 1980). Hereto, TA integrates the studies from different scientific fields into a comprehensive impact assessment. These methods include scenarios, Life Cycle Analysis, characterisation of the technology and market studies (Van Den Ende et al., 1998).

Later TA became a more strategic tool for decision making rather than neutral input. Currently, there is a whole family of different types of TA studies, with different methods and goals. The 'original' Technology Assessment is now referred to as Awareness TA or Early Warning TA, as it was restricted to the analysis of possible negative effects (Van Den Ende et al., 1998). This is in contrast to Constructive TA, which aims not only to analyse (negative) effects of technology to society, but also to shape the technology in socially desirable directions. Constructive TA can be defined as 'broadening the decision-making process about technological innovation by including as many relevant societal actors as possible, aiming at an optimal alignment between technological and societal developments' (Van Den Ende et al., 1998). Like the other forms of TA, Constructive TA has diverse methods allowing each participant in the process to emphasise different aspects (Schot and Rip, 1997). In contrast to Awareness TA, Constructive TA is not performed by neutral observers, but by actors with their own interests, goals and values. Actors, like representatives of industry, consumer organisations or environmental organisations, define the direction of the development and implementation of the new technology. To reach a consensus, the actors should not only have knowledge of the impact of the technology, but also of the interests and motives of the different actors.

1.4. Introducing the CCS case

After this short overview of how technologies and their acceptance can be analysed, as well as the role of values in the perception of the relation between technology and environmental problems, I will now focus on CCS.

According to the IPCC definition 'CCS involves the use of technology, first to collect and concentrate the CO_2 produced in industrial and energy related sources, transport it to a suitable storage location, and then store it away from the atmosphere for a long period of time' (IPCC, 2005). CCS is thus a chain that consists of three steps, namely capture, transport and storage. Each step has one or more elements and each element contains several components, as presented in Figure 1-1. In Annex 1.A I will describe the several components and their combinations that lead to complete CCS chains in more detail.

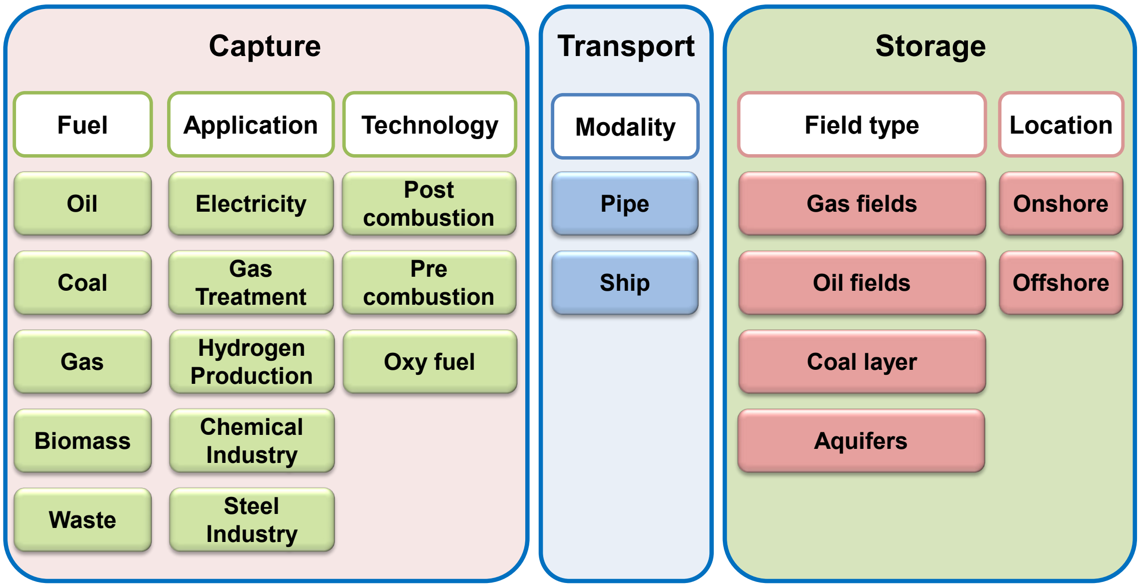


Figure 1-1 The three different steps, elements and components of CCS.

It is important to notice that the term CCS does not reflect a single technology, but relates to configurations of different components. For instance, CO_2 can be captured with a post combustion technology at a coal-fired power plant and be transported by pipeline to an onshore depleted gas field. These processes require completely different considerations compared with CO_2 capture from a refinery, which is transported by ship to an offshore oil field. In Figure 1-2 an artist's impression is given of various chains. Coal-fired power plants and natural gas-fired power plants both contribute for approximately 12.5% to the Dutch CO_2 emissions. In Annex 2 of this thesis more information on the Dutch CO_2 emissions is provided.

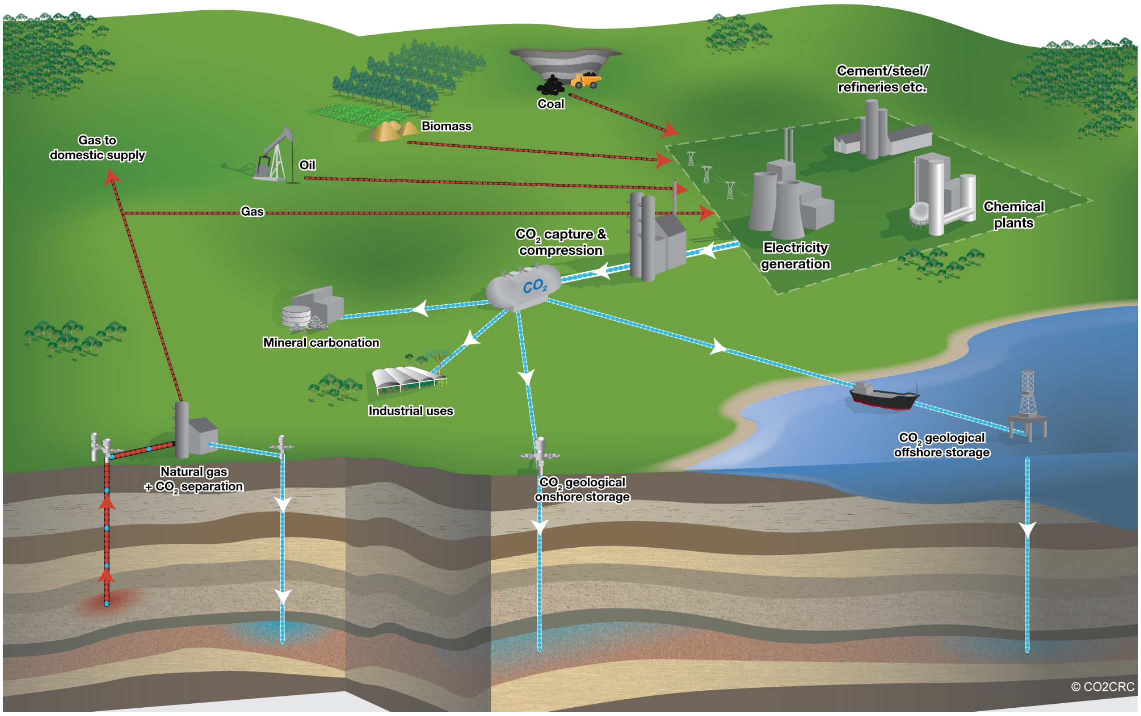


Figure 1-2 Artist impression on different CCS chains (Courtesy of CO2CRC, 2014).

Since the 1970's CO_2 has been injected into oil reservoirs with the aim to increase oil production. CO_2 makes oil less viscous and the increase in pressure pushes the oil out of its reservoir, which is referred to as Enhanced Oil Recovery (EOR). CCS as a greenhouse gas mitigation option was first proposed in the 1970's, but little research was done until the early 1990's (IPCC, 2005).

In the last decades, several studies have been performed to assess the potential of CCS for climate change mitigation. These studies analysed the amounts of emitted CO_2 at stationary sources, the CO_2 storage capacity in the subsurface and/or their combinations (Dahowski et al., 2009; Farla et al., 1995; IEAGHG, 2002; Orr, 2009; van den Broek et al., 2008). The obtained knowledge was used to compose different scenarios on future global CO_2 emissions, in which CCS played an important role to reduce CO_2 emissions (IEA, 2014b; Shell, 2013; WEC, 2013).

One backcasting scenario of the IEA (2014b) aims to limit global temperature rise to 2°C, which world leaders accept as the maximum temperature rise before dangerous climate change will occur (UNFCCC, 2009). This scenario should lead to a CO_2 emission reduction of approximately 50% in 2050 compared to CO_2 emissions in 1990 as presented in Figure 1-3. According to that study, CCS should contribute 6.9 gigatonne (Gt)[1] CO_2 per year to this emission reduction in 2050. This amount is comparable with the 'Symphony' scenario of the World Energy Council (WEC, 2013). The 'climate friendly Mountain' scenario of Shell (2013) projected a capture rate of 10 Gt CO_2 per year.

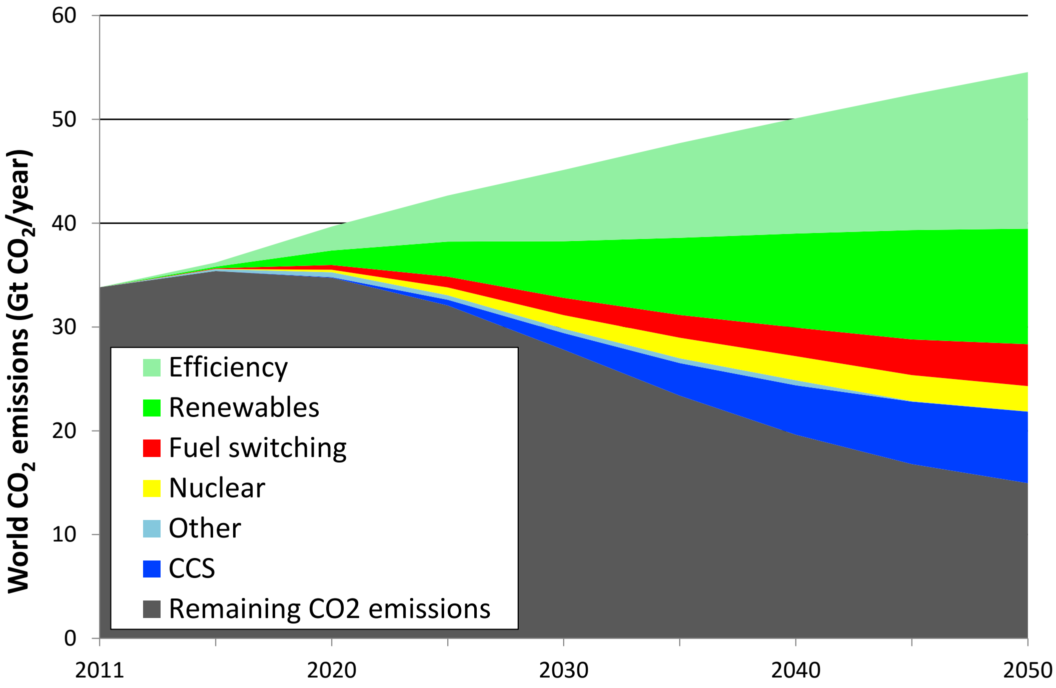


Figure 1-3 Example of an energy scenario to keep climate change below a temperature rise of 2°C (IEA, 2014b).

WWF and Greenpeace both provided scenarios with much stronger CO_2 reductions of 80-90% in 2050 compared to the 1990 level (Greenpeace, 2012; WWF, 2011). In these scenarios CCS is not used to reduce CO_2 emissions.

[1] A gigatonne CO_2 = a billion tonne CO_2 = 10^{12} kg CO_2. See annex 1 for abbreviations and a list with examples of different amounts of CO_2 emissions.

Project name	Country	Volume Mt CO_2/y	Start date	CO_2 source	Storage type
Val Verde Natural Gas Plants	US	1.3	1972	Natural Gas Processing	EOR
Enid Fertilizer	US	0.7	1982	Fertiliser Production	EOR
Shute Creek Gas Processing	US	7.0	1986	Natural Gas Processing	EOR
Sleipner CO_2 Storage Project	Norway	0.9	1996	Natural Gas Processing	Aquifer
Weyburn-Midale Project	Canada	3.0	2000	Synthetic Natural Gas	EOR
In Salah CO_2 Storage	Algeria	0[a]	2004	Natural Gas Processing	Aquifer
Snøhvit CO_2 Storage Project	Norway	0.7	2008	Natural Gas Processing	Aquifer
Century Plant	US	8.4	2010	Natural Gas Processing	EOR
Air Products EOR Project	US	1.0	2013	Hydrogen Production	EOR
Coffeyville Gasification Plant	US	1.0	2013	Fertiliser Production	EOR
Lost Cabin Gas Plant	US	0.9	2013	Natural Gas Processing	EOR
Petrobras Lula Oil Field	Brazil	0.7	2013	Natural Gas Processing	EOR
Boundary Dam	Canada	1.0	2014	Power production	EOR
Total		26.6			

Table 1-1 Overview of realised large-scale CCS projects until October 2014 (GCCSI, 2014a). Large-scale is defined as projects with a size of at least 0.8 Mt CO_2/year for coal-fired power plants or 0.4 Mt CO_2/year for gas-fired power plants and industrial processes. This equals approximately 150 megawatt (MW) electrical output.[a] The project injected 1 Mt CO_2/year before suspension in 2011.

Current status of CCS

Compared to the large role of CCS in some scenarios the actual application of CCS is limited. Until October 2014 thirteen large-scale CCS projects have been realised worldwide. In total these projects inject 26.6 mega tonnes (Mt) CO_2 per year, as depicted in Table 1-1 (GCCSI, 2014a).

The Boundary Dam project in Canada, which started in October 2014, is the only project that captures CO_2 on a large-scale from a power station, which is an important step towards large-scale implementation (SaskPower, 2014). The other projects produce (nearly) pure CO_2 from industrial processes in which separation (capture) is not needed.

In spite of successful realization of the abovementioned projects the contribution of CCS to mitigate climate change will likely be low with the current implementation speed (Scott et al., 2013). The Global CCS Institute (GCCSI) identified 44 plans for future CCS projects that are planned to be realised before 2020, with a potential of almost 75 Mt CO_2/year (GCCSI, 2014a).

Many studies have conducted Life Cycle Analyses (LCA) of CCS in the power sector (Corsten et al., 2013; Zapp et al., 2012). These studies compared the direct and indirect emissions of power plants with and without CCS. Their results were more or less similar: almost all other emissions, except CO_2, increased with CCS during the whole life cycle. The main cause for the extra (indirect) emissions was the extra energy needed for capture.

Compared to other low carbon technologies the costs of CCS hold a middle position. Some renewable technologies like onshore wind and geothermal energy are cheaper than CCS, whereas offshore wind and solar energy are more expensive compared to CCS (Figure 1-4).

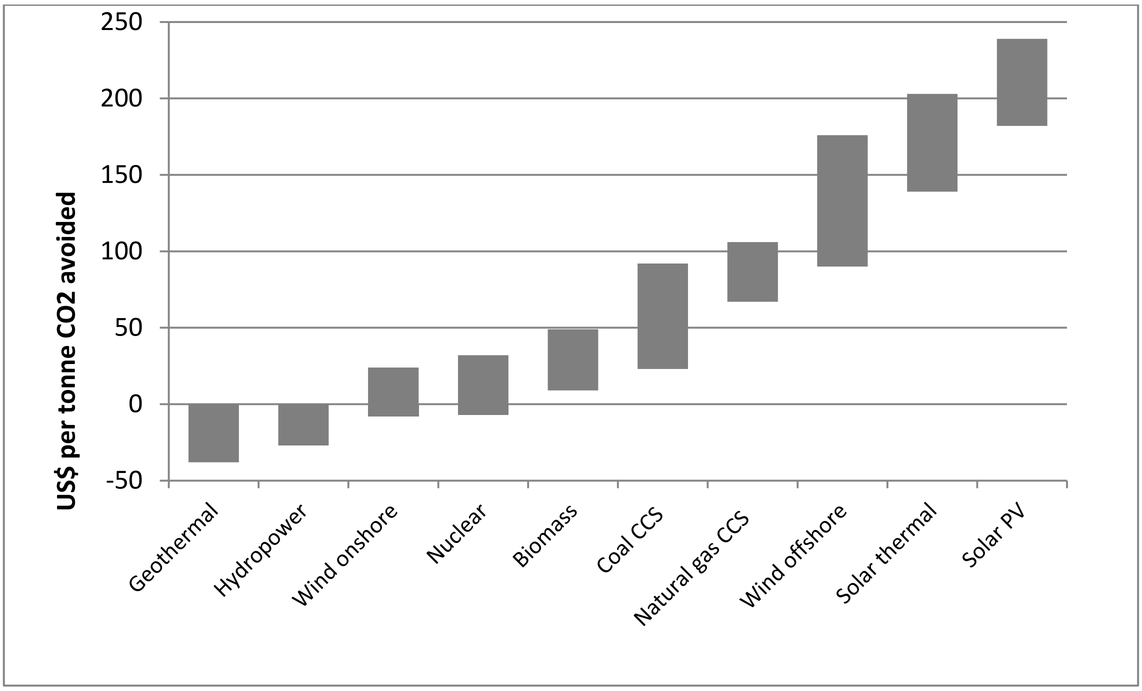


Figure 1-4 The abatement cost of low carbon technologies in US$ per tonne of CO_2 (GCCSI, 2011c).

Policy concerning CCS

With the exception of EOR, in which CO_2 is used to enhance production of oil, CCS costs money. Although the reduction of CO_2 emissions with CCS is less expensive per tonne CO_2 than some other low carbon technologies, it is still financially unattractive for companies to implement CCS. Hence, the IEA encourages governments to create more incentives to promote CCS (e.g. IEA, 2013b).

Many governments are supportive towards CCS, but do not always make CCS policy (EU, 2014; UK, 2014; US, 2013). In the Netherlands a covenant on the future of the energy system was agreed upon by representatives of the employers, labour unions and environmental organisations, which was later adopted by the Dutch government (Economic Affairs, 2013; SER, 2013). In this deal CCS was considered inevitable to keep climate change within safe limits and the government was asked to develop a long-term strategy. Thus, the Dutch government in principle supports CCS, but the actual implementation in the Netherlands is slow.

Policy on CCS has been investigated in several studies, which usually describe current policies (Meadowcroft and Langhelle, 2011; Pollak et al., 2011). Additionally, the potential effects of introducing specific policy instruments or the requirements for implementation have been analysed (Groenenberg and de Coninck, 2008; Schumacher and Sands, 2006).

For example, an evaluation of a European Union (EU) CCS subsidy scheme was examined by Lupion and Herzog (2013). They concluded in their study that this scheme was too inflexible to adjust to the changing financial and energy climate. Additionally, a comprehensive climate policy in different EU Member states was lacking. As such, the scheme was unsuccessful to achieve CCS implementation.

Furthermore, several CCS roadmaps have been developed (CSLF, 2011; DOE and NETL, 2010; IEA, 2013b). Hendriks and Koornneef (2014) generated a roadmap for the introduction of CCS in the Netherlands, which is depicted in Figure 1-5. Based on stakeholder analysis they developed a CCS vision for 2050 and defined necessary actions from industry and government to realise this ambition. Furthermore, the results indicate that for instance, the Dutch government needs to create a long-term energy and climate policy. The contribution of CCS should be defined and its relevance communicated to the public.

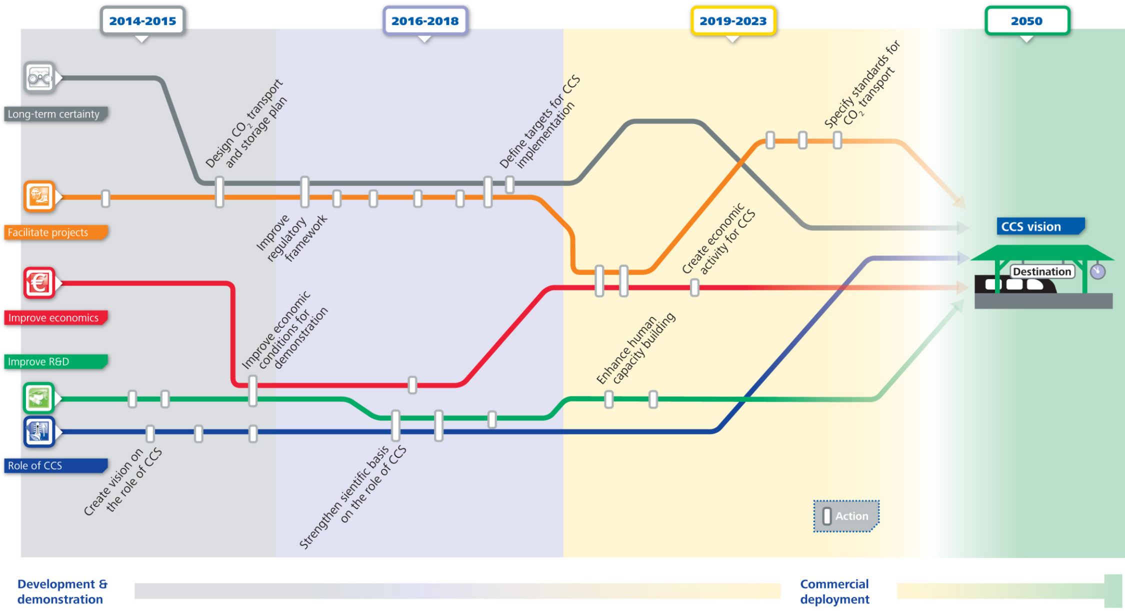


Figure 1-5 CCS implementation roadmap for the Netherlands (Hendriks and Koornneef, 2014).

The IEA (2013b) formulated key actions for the next seven years in their roadmap to lay the foundation for scaled-up CCS deployment, which requires serious dedication by governments and industry. The agency pleaded for example for the introducing of financial support mechanisms for demonstration projects and early deployment of CCS, as well as the development of national laws.

These studies focused on how CCS policy incentives could be executed, but did not examine in depth why governments have not implemented such measures up till now. In other words an assessment of the intrinsic drive of governments to act is lacking, and these studies did not provide an answer in which circumstances politicians are enticed to act in order to stimulate implementation of CCS. Therefore, one of the major research questions in this thesis addresses the considerations and views of politicians and policy makers.

Public acceptance of CCS

Elected policy makers are influenced by opinions of others like the general public and stakeholders which includes interest groups and social movement organizations (Burstein, 2003). Assessing the public opinion will therefore help to understand the actions of politicians. Public perception of CCS has been analysed in several countries with surveys that addressed a large representative sample of the population (Curry et al., 2007; Ha-Duong et al., 2009; Itaoka et al., 2012; L'Orange Seigo et al., 2014; Sharp et al., 2009; Wallquist et al., 2012a). The knowledge of the general public on CCS is limited, which makes it difficult to measure '*real'* opinions. When actual knowledge on a topic is lacking, opinions are very unstable, making this a 'pseudo opinion' (de Best-Waldhober et al., 2009). To circumvent pseudo opinions, focus groups can be used to investigate public perception. These are small groups of individuals that discuss the topic in the presence of an expert who can answer questions that may arise (Bradbury et al., 2009; Oltra et al., 2010; Shackley et al., 2004; Upham and Roberts, 2011). A drawback of this method is the low number of participating persons, which can result in a non-representative sample.

Within the social science community it has been debated which method is preferable to measure opinions. Ter Mors and colleagues (2013) showed that a survey with balanced information provides the best results. In the Netherlands there have been several surveys in which a lay public was informed in a balanced way. The Dutch public was not enthusiastic on CCS, and graded this option of climate mitigation as average, or even slightly below average (de Best-Waldhober et al., 2012b). Renewable energy and energy efficiency were the preferred options by the general public. Nuclear energy was overall rated similarly compared to CCS, but with a higher standard deviation, as nuclear energy was perceived as more controversial. Whereas CCS was rejected by approximately 6.8 - 11% of the population, nuclear energy was rejected by 20%. On the other hand, nuclear energy has also more supporters in the Netherlands than CCS.

Trust and perceived risk were found to represent important determining factors for acceptance by the general public, which is in accordance with studies on acceptance of other technologies (Shackley et al., 2009; Terwel et al., 2011; Wallquist et al., 2012b). Poor communication, distrust of the project developer, lack of public engagement, perceived negative local impact, a relatively unknown technology and the absence of benefits for the local population were defined as important factors to explain local opposition against CCS (Ashworth et al., 2011 and 2012; Markusson et al., 2011; Oltra et al., 2012).

Most people do not have the in-depth knowledge of risks and benefits associated with a technology. Instead the public bases its opinion on the information provided by experts of Non-Governmental Organisations (NGO's), industry, government or the scientific community. Organisations who share the values of an individual are perceived more trustworthy compared to organisations with different values (Siegrist and Cvetkovich, 2000). With regard to the CCS topic Dutch citizens have less trust in industrial organizations than in environmental NGOs (Terwel et al., 2009).

Stakeholder analysis

Shackley and colleagues (2007) showed that stakeholders, like NGOs, industry and academia in Europe were moderately to strongly positively inclined towards CCS. However, NGOs were much less enthusiastic compared to the energy industry and academic stakeholders. Johnsson et al. (2010) showed that NGOs considered the threat of climate change more serious than the other groups. NGO respondents perceived CCS as a far more attractive option compared to nuclear energy, but much less desirable than renewables. A survey in Germany showed similar trends, but opinions of all stakeholders on CCS were less positive compared to other international studies (Fischedick et al., 2009). Corry and Reish (in Markusson et al., 2012b) provided a detailed overview of the positions of NGOs on CCS, and the underlying argumentation. They recognised that the differences between opinions of distinct NGOs on CCS are based on the different perceptions of the problem definition, which is seen in many 'wicked' problems. For instance, the environmental organisation Bellona considers solving the climate problem itself as a main issue. Greenpeace advocates changes in the energy system, and perhaps even of the whole economic system, as it is of the opinion that the latter is the underlying cause for climate change.

Integrated studies on CCS

Policymakers and other stakeholders base their opinion on CCS on multiple considerations involving social, environmental, economic and technical issues. However, many studies on CCS have focused on particular aspects only, as was shown by Michael et al. (2014). This literature overview described that a majority of the studies were related to either social, technical, environmental or economic issues, but almost none addressed all four fields.

Markusson et al. (2012a) used a Technology Assessment approach to develop a multi-faceted, socio-technical framework to analyse the possible future development of CCS and decision making by stakeholders. They proposed 7 topics of uncertainties that a decision maker has to deal with. These include for example uncertainties in safe storage, economic and financial viability and public acceptance of CCS.

In the EU ACCSEPT project also an integrated approach was used to assess CCS (de Coninck et al., 2009; Shackley et al., 2009). In this project 12 critical questions were defined, which needed to be addressed before CCS could be reliably, effectively, efficiently, justifiably and safely implemented within the EU. The questions covered a wide variety of different fields, including issues on science and technology, law and regulation, economics and social acceptance. Based on the answers to these questions they concluded that there were no compelling scientific, technical, legal, or economic reasons why CCS could not be widely implemented in the forthcoming decades as part of a climate change mitigation strategy. However, de Coninck et al. (2009) referred to the important role of governments to facilitate this deployment by providing a strong policy framework with sufficient and long term incentives for CCS.

1.5. Goal and outline of this thesis

This thesis focuses on the debates about CCS, which is a technology that aims to reduce the negative environmental impact of fossil fuels use. CCS prevents the entry of CO_2 into the atmosphere and may therefore contribute to climate change mitigation. The expectations of the potential of CCS are high, but there is also societal contestation. Many scientists and policy makers perceive that large-scale implementation of CCS is essential to mitigate climate change (IEA, 2013b). However, the actual deployment may be too slow for CCS to fulfil this role. To increase the speed of implementation more policy incentives are required (Scott et al., 2013). By understanding the discourse on CCS, one can get an idea whether society is willing to provide these incentives. It is interesting to note that environmental organisations evaluate CCS very differently (Corry and Reiner, 2011), but are for instance harmonious in rejecting nuclear energy and accepting solar energy. Therefore, CCS is an interesting casus to analyse the underling motives that lead to acceptance or rejection of a new technology. Ultimately this understanding may result in communication and technology development strategies in which the knowledge and arguments of all societal stakeholders are included. This may help to design a technology as a societally acceptable option. In this thesis I analyse the different views on CCS and the underlying motives, which can serve as a first step in a Constructive TA.

As described in the previous section, there are several natural science approaches to generate information on the characteristics and costs of CCS, in order to inform policymakers and other stakeholders. The social science approaches that I introduced help to better understand the social acceptance. I described that CCS is an environmental technology that may help to reduce CO_2 emissions. However, the current implementation of this technology is lacking behind compared to several scenario and roadmap studies that showed possible routes towards emission reduction to prevent dangerous climate warming above 2°C.

I mentioned the shortage of government stimulation as one of the reasons to explain the lack of substantial implementation of CCS, although the exact reasons for this apparent reluctance remain unknown. Furthermore, I showed that public acceptance of CCS and the role of stakeholders are important determinants for successful implementation of CCS. Our current understanding of these factors is, however, too limited to explain the societal and policy processes around CCS.

In order to fill this knowledge gap, I use a multidisciplinary approach in this thesis to study CCS implementation in the Netherlands. I investigate which considerations drive the decisions of the government, and how these are influenced by the opinion of the general public and other involved stakeholders. The main research question is:

How is CCS perceived by different actors in society and how does their opinion influence CCS development and implementation in the Netherlands?

In this thesis I address the views and actions of three different main actors in society: the government, including political parties, the general public, and finally the scientific community.

Many different arguments either in favour or against CSS are used in the debate. In chapter 2 we therefore start with a comprehensive inventory of all arguments in favour or against CCS, based on discussions with experts from the field, such as scientists, politicians, industry and NGOs. As CCS is not one homogeneous technology, but consists of different chains, we separated arguments that apply to specific configurations only versus arguments may be applicable in a more generic way. A thorough analysis of the arguments can help policy makers to better found decisions and improve the quality of the debate.

The inventory of all arguments in chapter 2 was independent of the importance of the arguments. As such, the significance of different arguments for decision making was not taken into account. However, in reality not all arguments are weighted equally, as some are deemed more important than others, based on values of an individual. A systematic investigation of how citizens evaluate pro and con arguments is essential to improve understanding of the effect of communication on citizens' attitudes towards CCS implementation. In chapter 3 we determined the persuasiveness, importance and novelty of 16 arguments in favour and 16 arguments against CCS in the Dutch population. The arguments related to topics on climate change, risks to human welfare, the impact on the energy system and effects on electricity prices and economic growth. Latent class models were used to identify segments of the population with different preferences.

In chapter 4, the political debate in Dutch Parliament on CCS is unravelled. Studying the political debate is a very insightful way to understand a societal debate since politicians represent different voter groups. Moreover, arguments used in political debates are perfectly recorded and traceable in archives. In this chapter we analysed the views of the different Dutch political parties on CCS, and examined the underlying arguments that led to these opinions. The arguments with regard to CCS were related to the political parties' standpoints on climate change. As CCS is a climate mitigation technology we hypothesised that strong climate ambitions would facilitate acceptance of CCS. Additionally, we looked for relations between political ideology and the CCS standpoints.

Science plays an important role in the development of CCS and is a source for information for policy makers. CATO as the Dutch CCS programme is analysed in chapter 5. First, we describe the issues that have dominated CCS research in the Netherlands. Second, the impact of CCS research in the Netherlands is assessed. Finally, we evaluate how the scientific community interacted with the on-going societal debate.

In chapter 6 the 'Barendrecht' storage project is discussed. The Netherlands is a natural gas producing country with concomitant infrastructure. CO_2 storage in depleted gas reservoirs is therefore seen as a suitable storage option, as these gas reservoirs have by far the largest storage capacity compared to aquifers and depleted oil fields. The Dutch storage capacity is estimated approximately 10 Gt CO_2, of which almost 90% is located onshore (Vosbeek and Warmenhoven, 2007). Given the importance of onshore CO_2 storage to facilitate large-scale CCS implementation the government tendered for an onshore demonstration project as a first step (Economic Affairs, 2009b). This resulted in the proposed Barendrecht project by Shell. The project received strong local opposition and was heavily debated in Parliament, which resulted in long delays and ultimately into cancellation. The final decision on the cancellation of the project was the authority of the national government. In this chapter we therefore analyse the national decision processes related to the Barendrecht project, including the influence of local opposition. A better understanding of why the government changed position during the debate, ultimately resulting in termination of a prominent CCS project, will help in the planning of future projects.

Finally, in chapter 7 I summarise my findings, and give recommendations for the political and societal debate on CCS, as well as for its development into a more societal acceptable technology.

1.A. Annex: Background information in CCS chains

A CCS chain consists of the three steps capture, transport and storage. Each step has one or more elements. Each element contains several components, as seen in Figure 2-2.

First step: capture

Element: fuel

The fuel is the input for the energy conversion process (the application). The origin of the carbon in the fuel that needs to be captured may be either fossil or biomass. The emission of CO_2 per energy unit varies depending on its source. The CO_2 emission factor of natural gas is about 56 kg CO_2/GJ, 75 kg CO_2/GJ for oil and 95 kg CO_2/GJ for coal (Blok, 2007). When coal is burned the emitted CO_2 per energy unit is therefore approximately doubled compared to natural gas (IPCC, 2005). Thus, the effect of CCS greatly depends on the fuel type. When biomass is used, the net emission towards the atmosphere is close to zero. In other words, capturing and storing CO_2 after conversion of biomass into useful energy results in a carbon sink, also labelled as negative carbon emissions. Waste is often a combination of biomass, like wood, crop and food residues and fossil fuels that are part of plastics as feedstock.

Element: application

The focus of CCS is on capturing CO_2 at large stationary sources since these are the most suitable for CCS on the short and midterm (IPCC, 2005). There are many processes that convert primary energy into useful products. Each process emits CO_2 in different concentrations and at a different pressure. This strongly determines the possible CO_2 capture processes and for example the energy needed to retain high concentrations CO_2. The carbon concentration in flue gases of a gas-fired power plant is about 3-7%, whereas the concentration for coal-fired power plants is much higher (14%), making CO_2 capture of coal-fired power plants cheaper per tonne of CO_2, compared to gas-fired power plants. However, the total CO_2 emitted by a coal plant per kWh is double compared to a gas-fired power plant, and thus it needs to capture approximately double the amount of CO_2. The concentration of CO_2 in flue gases of steel plants is higher than for power plants (up to 27%) (IPCC, 2005). At facilities where ammonia and/or hydrogen are made, CO_2 at high concentrations is produced as a by-product. Natural gas that is produced from a subsurface reservoir can contain CO_2. When the natural CO_2 concentration is too high, the CO_2 must be removed to meet the proper specifications. With this natural-gas treatment process, it is often also possible to obtain high concentrations CO_2 at high pressure. These high CO_2 concentration flows do not need expensive and energy consuming separation techniques and therefore have a positive influence on the economics and energy balance of CCS (IPCC, 2005).

Element: capture technology
There are three main approaches to CO_2 capture. The first is post-combustion, where the CO_2 is separated from the flue gases. This is typically done with chemical solvents. With pre-combustion systems the fuel is transformed into a mixture of H_2 and CO_2. This gas is then separated into almost pure hydrogen and CO_2.The last approach is oxy-fuel combustion, which is also referred to as denitrogenated combustion. This process uses oxygen instead of air for combustion of the fuel, producing mainly CO_2 and H_2O. After condensation of the steam in this oxy-fuel process, a highly concentrated CO_2 stream is obtained (IPCC, 2005). The concentration of the captured CO_2 depends on the process. For power plants it varies between 80%-90% (IPCC, 2005).

For electricity production all of the above combinations of fuel and capture technology can be used. Ammonia and hydrogen are produced using technology that is very similar to the pre-combustion process. With natural gas sweetening no energy is converted, so no combustion takes place. The process is, however, comparable with post- combustion capturing, but at high pressures and under the absence of NO_X (IPCC, 2005).

Second step: transport
Before CO_2 is transported, it is compressed to reduce the volume and increase the density of CO_2. Commercial-scale transport uses pipelines or ships for gaseous and liquid CO_2. For transport by ship temporary storage and loading facilities onshore are needed. Ship transport is seen as more flexible compared to pipelines as shipping routes can change and pipeline traces cannot. However, transport by ship is not always possible onshore since there are not always rivers or canals available close to onshore storage sites. Ship transport becomes cost-competitive with pipeline transport over a large distance. The breakeven point shifts towards pipelines at larger quantities (IPCC, 2005).

Third step: storage
Element: field type
CO_2 can be stored in (nearly) empty gas fields, oil fields, coal layers or aquifers. The appropriateness of a subsurface storage location depends on many factors. Each location has its own characteristics with their pros and cons. At the 10^{th} International Conference on Greenhouse Gas

Control Technologies, GHGT10, the phrase 'nothing is as unique as a storage site' was often mentioned (de Vos and van Egmond, 2010). The Dutch aquifers that might be considered for CO_2 storage contain brine, so water in the aquifer is not potable and has no economic value.

However, we try to make a general comparison between different types of reservoirs, as summarised in Table 1-2. When dealing with CO_2 storage two types of risks are involved for all storage sites. The first risk entails that the CO_2 storage capacity or the injection rate is smaller than expected. This is an economic risk for the company that wants to store the CO_2. For example, if the injectivity turns out to be lower than forecasted, the CO_2 injection rate cannot be achieved. If this situation occurs, it may be possible to drill extra injection wells, but this will add to the total costs of the project. It is also possible that the total capacity is lower than estimated in advance, resulting in an economic setback. From Table 1-2 it becomes clear that gas and oil fields have in general the lowest economic risk. As gas and oil fields have been used for production, an enormous amount of data of the reservoirs has been generated. With this knowledge it is possible to make in depth models of the reservoir. These models can predict the CO_2 flow through the reservoir and therefore calculate how much CO_2 can be injected. The economic risk is therefore smaller than when aquifers or coal layers are used.

The second risk is a safety risk, and revolves around the possibility that stored CO_2 may escape to the surface. The presence of gas in the reservoir is a strong indication that the reservoir is gastight. When these fields will be used for CO_2 storage they will be (almost) empty. This means, in the Dutch situation, that the pressure inside the reservoir can be up to hundreds of bars lower than the surrounding rocks. The injected CO_2 will partly remove this relative vacuum. Even if there might be a leakage of the reservoir, water from outside the reservoir will migrate inwards rather than the CO_2 outwards. This is a strong advantage of gas fields, as it renders them relatively safe. In some oil fields also natural gas is found, giving a strong indication for a good seal. There are also many oil fields that do not contain natural gas (anymore). For those oil fields it is more difficult to prove that they are gastight. This is also the case for aquifers and coal layers.

However, as depleted natural gas and oil fields have been used for production, they contain wells. These wells can be reused for injection, providing an economic advantage, but (abandoned) wells are also seen as the most probable leakage pathways for CO_2 storage projects (IPCC, 2005). Old wells therefore need to be abandoned in a proper way, to avoid potential CO_2 leakage during future use. Some aquifers also have wells, when oil or gas drillings have been carried out in potential fields below the aquifer. In that case the well penetrates the aquifer. If that is not the case, all the wells can be designed specifically for CO_2 storage. A good site characterisation is always necessary to determine the quality of the seal and the wells.

Finally it is interesting to note that the injection of CO_2 in oil fields and coal layers can result in more oil or natural gas, respectively. This Enhanced Oil Recovery process is being used in the US and Canada since many decades.

Mainly relevant for	Issue	(Nearly) empty gas fields	Oil fields	Coal layers	Aquifers[c]
Safety	Gastight	(virtually) Proven on geological timescale	Sometimes proven	Sometimes proven	Unknown
Safety	Existing wells	Few	Many	None - many[b]	None-many[d]
Safety	Pressure compared with surroundings	Much lower[a]	About equal	Equal or higher	About equal
Safety/ economics	Geological knowledge of location	Large	Large	Little	Medium
Economics	Extra economic benefits	(almost) None	Oil production	Natural gas production	None
Economics	Economic risk that injection does not go according to plan	Low	Low	Higher	Medium

Table 1-2 General characteristics of the four field types of storage locations prior to the start of a storage project for Dutch case.

[a] When water can flow in the reservoir the pressure will be equalised. This is seldom the case for the Dutch situation and will be known beforehand from the gas production.
[b] Depending on whether the layer is used for natural gas production (CBM).
[c] non-potable and non-economic water.
[d] Depending on whether oil or gas fields below the aquifer are used for production.

Element: Location
For the properties of the subsurface reservoir it is not relevant whether it located onshore or offshore. However, storing CO_2 onshore is in general less expensive than offshore. IPCC (2005) estimates that in Europe the cost for onshore is 1.7 \$/tonne CO_2 stored, whereas offshore the cost is 6.0\$ per stored tonne CO_2. Another important difference is the (perceived) risk for humans and the environment, as onshore storage is deemed more risky.

Dutch CCS chains
Based on Figure 2-2, an enormous amount of different CCS configurations can be defined. There are for example 5 different fuel types for power plants and 3 different capture technologies, resulting in 15 capture configurations for power plants. Moreover, the CO_2 can be transported in two different ways and stored in four different types of reservoirs, either onshore or offshore, resulting in 240 different configurations for CCS in the electricity sector. For the other sectors the variety is less, since not all configurations are possible or logical. We estimate that there are around 500 different CCS chains that can be considered logical based on the components in Figure 2-2.

In the Netherlands a dozen CCS projects have been proposed, as summarised in Table 1-3. As can be seen from the table, many different configurations of CCS are proposed. In the Dutch situation the emphasis lies on using gas fields for storage. Until now the only one that has been realised is the offshore gas treatment K12-B project. This project started injection in 2004 and is operated by Gaz de France.

Project	Fuel	Application	Technology	Transport	Field type	Location
Barendrecht (Shell)	Oil/Gas	Refinery	Pre combustion	By pipe	Gas field	Onshore
Geleen (DSM Agro)	Gas	Ammoniac production	Pre combustion	On own site	Aquifer	Onshore
MAGNUM NUON	Gas & coal	Electricity production	Pre combustion	By pipe	Gas Field	Onshore
K12-B	Gas	Gas treatment	Post combustion	On own site	Gas field EGR[a]	Offshore
ROAD (E.ON & Electrabel)	Coal & biomass	Electricity production	Post combustion	By pipe	Gas Field	Offshore
Essent/RWE North NL	Coal	Electricity production	Post combustion	By pipe	Gas Field	Onshore
SEQ Drachten[c]	Gas	Electricity production	Oxy fuel	By pipe	Gas Field EGR[a]	Onshore
Tata Steel	Coal	Steel	Oxy fuel			
Twence	Waste	Electricity productiond[d]	Post combustion			
Air Liquide Rozenburg	Gas	H_2 production	Pre combustion	Pipe/ship	EOR[b]	Offshore[e]

Table 1-3 A selection of the (proposed) Dutch CCS projects split according to the defined components (CATO, 2011). Open cells indicate that the total configuration has not been decided yet.
[a] Enhanced Gas Recovery
[b] Enhanced Oil recovery
[c] Scope and name of the project have changed several times. Currently the project name is Pegasus and it aims to use low caloric natural gas with high CO_2 concentrations for power generation. The use of pure oxygen should prevent gas treatment.
[d] Waste burning with electricity production, this application is not mentioned in Figure 2-2 as it is too specific.
[e] Oil fields in Danish territorial part of the North Sea.

2. Mapping the CCS benefits and drawbacks[1]

2.1. Introduction

It is widely accepted that burning fossil fuels contributes to climate change. Governments have agreed that the global temperature should not rise more than 2°C compared to pre-industrial levels, as has been reconfirmed in the UN Cancun climate summit (UNFCCC, 2010). This target implies a maximum concentration of 450 parts per million (ppm) CO_2 in the atmosphere. This requires deep cuts in carbon emissions and therefore a transformation of our energy system towards a low carbon energy system. Carbon capture and storage (CCS) can be one of the mitigation options to achieve the necessary deep cuts in CO_2 emissions.

CCS is a contested technology. It is highly discussed in the public media by different societal groups, which have diverse visions and expectations regarding CCS. For some, CCS is the technology that we need in order to combat climate change while others see it as a technology that prevents a real transformation to a sustainable energy system. For CCS to be applied at a large-scale, public support is necessary (IEAGHG, 2010). The lack of public support severely reduces the chance of success of a new technology. For instance, the public debate on nuclear energy in the Netherlands and Nordic countries has resulted in a ban on new nuclear power plants (Arentsen, 2006). In the Netherlands there has been a strong debate on a CO_2 storage project under the town of Barendrecht. This debate ultimately resulted in the cancellation of the project and other CCS onshore plans in the Netherlands.

When a technology is contested and public debates are taking place, often a wide variety of arguments in favour or against the new technology are used. It is important to have insight in the arguments that are used in the public debate, because these arguments influence public opinion. An analysis of the arguments can aid policy makers to make better founded decisions and in general improve the quality of the debate. In scientific papers often only a few arguments are discussed, e.g. the environmental impact of CCS, costs or public perception (Michael et al., 2014). In the ACCSEPT project a more integrated approach regarding the acceptance by society was chosen (de Coninck et al., 2009). Twelve critical questions on CCS were asked and analysed,

---

1 This chapter is adapted from: S. van Egmond and M.P. Hekkert, 2012. Argument map for carbon capture and storage, International Journal of Greenhouse Gas Control, volume 11, S148–S159.

before the authors came to the conclusion that the implementation of CCS would be advisable. However, a complete mapping of all arguments related to CCS has not yet been performed.

In this chapter we therefore present the pro and con CCS arguments that are used by stakeholders in the Netherlands. By presenting these arguments concisely and clearly, we aim to contribute to a higher quality of the debate. The arguments are visualised in a so called 'Argument map' (Argumentenfabriek, 2010). Experience with other topics, such as nuclear energy and adaption of the retirement age, has shown that translating complex topics into such a compact graphical representation helps people to obtain a better-informed opinion. In general, this results in a higher quality of the debate and a more balanced view for either advocates or opponents (Kalshoven, 2010).

In addition to mapping the arguments, we will discuss the arguments in relation to different CCS configurations. CCS is an umbrella term for a wide range of different configurations of separate technologies (Figure 1.1), which constitute a specific chain when they are combined with each other. The conceptual diffuseness about what CCS actually entails may lead to misunderstandings on CCS, as advocates and opponents of the technology may implicitly have very different technological configurations in mind. Whereas several arguments are generally applicable for all CCS chains, some are only valid for a particular configuration.

This chapter is structured as follows: We start in section 2.2 with the method of the inventory and clustering of arguments, followed with the presentation of the map. In section 2.4 a framework of the different elements of CCS is presented and discussed. In section 2.5 this framework is applied to the different arguments, followed with an explanation of the different arguments. We end with a discussion and conclusion in section 2.6.

2.2. Argument map methodology

This study was financial supported by the Dutch research programme on CCS (CATO). To ensure that the inventory of the arguments was unbiased by advocacy towards CCS, an independent and external consultancy was asked to lead the process[1]. This company, called

[1] The first author of this paper was the CATO communication manager who commissioned the development of the Argument map and was closely involved in all steps of the process.

Argumentenfabriek (Argument factory), is specialised in gathering and grouping arguments. Previous research on the arguments used in the Dutch media was provided to the company (Kliest, 2010) as preparation for the workshops where experts were asked to make an inventory of the arguments. This list was expanded with opinions of both opponents and advocates of CCS (Greenpeace, 2008b; Nackenhorst et al., 2009; Vosbeek and Warmenhoven, 2007).

The central question of the map 'What are the arguments for or against CCS in the Netherlands?' was defined in consultation with the CATO programme. Due to the focus on the Netherlands, several CCS options were omitted. For instance, deep ocean storage was not considered, as the North Sea is too shallow for storage of CO_2 in sea water. In the inventory climate objectives were taken for granted. For example, a CO_2 emission reduction of 80% in 2050 compared to 1990 was deemed necessary. Consequently, arguments questioning climate change and/or the necessity for CO_2 reductions were not considered. Furthermore, only valid arguments were taken into account. Validity was decided by the participants of the workshops. Arguments could either be applicable for specific or for all CCS chains.

A brainstorm session collecting arguments for and a second brainstorm session gathering arguments against were held during the first expert workshop, (Utrecht University, 19th May 2010) in order to generate as many arguments as possible. Participants had to write down all the arguments they could think of. The opinion of the participants varied from against to neutral to in favour of CCS. The participants were quite capable of mentioning arguments that did not necessarily support their own opinion. Thus, advocates of CCS also referred to arguments against CCS, and vice versa. When the participants had finished their own inventory, arguments were collected during several rounds. Each person was only allowed to give one new argument during each round, to ensure that all participants could contribute equally. Furthermore, since arguments were projected on a screen, the other participants could improve upon the argument if they were of the opinion that the argument was factually incorrect. However, they were not allowed to discuss or refute an argument simply because of disagreement. After a dozen rounds all the arguments had been collected.

After this workshop the arguments were grouped into themes and checked for completeness with the original list. During the second workshop the different themes were discussed as well as the relevance of the arguments and their completeness (Utrecht University, 27th May 2010).

2.3. Argument map results

This process resulted in 57 arguments, of which 31 were opposed to CCS and 26 were in favour (see figure 2-1). The arguments could be divided into six themes:

- Climate
- Energy
- Environment
- Ethics
- Safety
- Economics

As we refer to an argument 'map', the different themes are called *districts*. Each district has arguments for and against CCS. Within districts arguments are grouped into a total of 21 *neighbourhoods*. An individual argument is referred to as a *street*.

It is important to note that the presented arguments do not cover the whole CCS debate. The arguments presented are seen as valid by the experts. For instance, a statement of a worried inhabitant 'I just do not want CO_2 under my backyard', may be a valid opinion, but is not an argument. In the map this example is transformed to the ethical argument: 'A solution that has little public support is not acceptable.'

Nomenclature for arguments of figure 2-1

1st Themes: Climate, Energy, Environment, Ethics, Safety or Economics (District)
2nd Attitude: For or Against
3th Group of arguments (A, B or C) (Neighbourhood)
4th Individual specific argument (Street)

Example
Climate-For-A: refers to the neighbourhood 'CCS is good for the climate', thus a group of arguments
Climate-For-A-1: refers to the individual argument (street) 'Together with renewable energy and energy saving, CCS reduces CO_2 emissions fast enough to avoid dangerous climate change.'

commissioned by: cato2 www.co2-cato.nl

Figure 2-1 Argument map for CCS in the Netherlands (Argumentenfabriek, 2010)

produced by: De ArgumentenFabriek The Argument Map © 2010

2.4. Different components in the CCS chain

To understand the applicability of the arguments for different CCS chains, we first provide some background. A CCS chain consists of three steps, namely capture, transport and storage. Each step has one or more elements and each element contains several components, as presented in Figure 2-2. We define an integrated CCS project as the configuration made up of all three steps and with at least one component for each element.

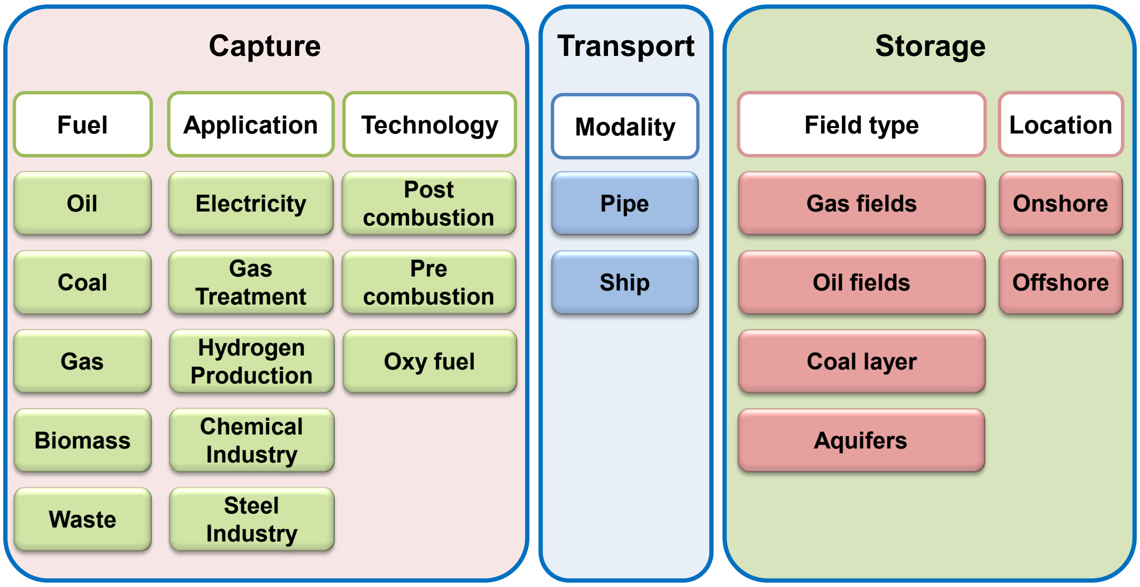


Figure 2-2 The different steps, elements and components of CCS.

For example, the capture step in Shell's proposed Barendrecht project in the Netherlands is done with the fuel (natural) gas, in a hydrogen production application with pre-combustion capture technology. The CO_2 is then transported by pipeline. In the final storage step the CO_2 is stored in a gas field at an onshore location. For details on different CCS chains, see Annex 1.A.)

2.5. Analysis of backgrounds and applicability of the arguments.

In this section, we will reflect on the arguments that are mentioned in figure 2-1 from the top to the bottom, starting on the left side. We give background information on the arguments and relate them to the different CCS chains, as some arguments apply to specific CCS chains, whereas other are more general.

It is not possible to address all 57 arguments in detail. Therefore we will discuss the arguments grouped on the *neighbourhood* level and discuss only a few arguments individually. After this discussion we will give an overview of the applicability of the arguments to the CCS chains. Applicability of individual arguments was scored for each component and/ or element. For instance, 'Power stations using fossil fuels will continue to emit CO_2 even with CCS', applies to CCS chains that use oil, coal, or gas to produce electricity. The methods of transport and storage are not relevant in this example.

2.5.1. Climate-related arguments

CCS is good for the climate (Climate-For-A)

This neighbourhood is the key argument for CCS. It is therefore applicable for all different CCS chains. However, multiple configurations are needed to contribute significantly to climate mitigation. For example, when Dutch onshore storage locations remain excluded, the potential contribution of CCS is reduced by more than fifty percent (Vosbeek and Warmenhoven, 2007). Supporters of this argument state that renewable energy and/ or energy efficiency alone are not capable of realising a reliable and economic energy system that will meet the necessary CO_2 cuts before 2050. Additionally, several arguments in this neighbourhood are applicable for specific applications that have limited possibilities for CO_2 reduction without CCS, such as the steel and chemical industry.

A special configuration of CCS is related to biomass, as this gives an option for negative emissions, or in other words enables the extraction of CO_2 from the atmosphere. Some scientists consider the limitation of the agreed 2°C temperature increase insufficient to avoid dangerous climate change. They also point out that a 450 ppm concentration of CO_2 in the atmosphere is still too high. They therefore share the opinion that deeper cuts in emissions are required, but that CO_2 should also be retracted from the atmosphere to stay within safe limits of climate change (Azar et al., 2010).

CCS makes international climate agreements (more) feasible (Climate-For-B)

CCS supports the prospect that the climate target may be reached without major changes in the energy system. Consequently, this seems an easy way out for countries that are dependent on fossil fuels. For countries like China, US, Russia and Australia that are fossil fuel producers with extensive coal reserves, CCS could be a more attractive option than a reduction of coal use. With this approach they do not have to depreciate their fossil fuel reserves. This neighbourhood is applicable to all CCS chains, except one individual argument that refers to coal-fired power plants ('If the Netherlands sets the example, countries with many coal-fired power stations like China are more likely to follow').

CCS is unnecessary for the climate problem (Climate-Against-A)

Opponents of CCS often point at the enormous potential for energy saving and renewable energy. They state that CCS is unnecessary, as renewable energy and energy saving can sufficiently contribute to avoid dangerous climate change. WWF (2011) developed a scenario, which leads to a fully renewable energy system in 2050, without the use any CCS chains.

CCS is bad for the climate (Climate-Against-B)

This neighbourhood states that CCS will not help to reduce CO_2 emissions. Several individual arguments of this neighbourhood are discussed below.

Power stations using fossil fuels will continue to emit CO_2, even with CCS (Climate-Against-B-1)

When CO_2 needs to be captured from a diluted source like power plants, not all CO_2 is captured. The percentage of captured CO_2 varies between technologies and the available budget. Systems are generally economically optimised for the lowest cost per captured CO_2, not for removal of all CO_2 in the flue gas. Since high costs are needed to capture the remaining last part, the capture ratio in practice is around 80-90% for power plants (IPCC, 2005). IEAGHG (2006) showed that the costs for capturing the last remnants of CO_2 reach exponential heights for post combustion, whereas the incremental costs for oxy-fuel applications are moderate. New approaches to reach higher capture rates have been proposed. Kunze and Spliethoff (2012), for example, anticipate the possibility to reach 99% capture at coal gasification power plants with new technology for reasonable prices. This argument is applicable for all chains generating electricity. The actual remaining CO_2 emission depends on the used capture technology.

It is unsure whether the CO_2 will remain underground long enough to avoid dangerous climate change. (Climate-Against-B-4)

This is a generic argument for all CCS chains. Van der Zwaan and Smekens (2009) have calculated the maximum allowable leakage of the total CO_2 storage portfolio from a climate perspective. They conclude that a leakage rate at or below 0.5% per year is needed for CO_2 storage being an economically competitive carbon-free energy option. IPCC (2005) states that for geological storage sites that are selected, designed and managed well, it is likely that the leakage will be below 1%

per 100 years, or even 1,000 years. Percentages could differ per type of reservoir, as risk profiles can differ for reservoirs (see Table 1-2 in Annex 1.A.)

2.5.2. Energy-related arguments

CCS keeps fossil fuel reserves accessible (Energy-For-A)

This neighbourhood assumes that climate is the limiting factor for fossil fuel use instead of the availability of fossil fuels, since the amount of carbon available in fossil fuels outnumbers the amount of carbon that the climate can deal with. Meinshausen et al. (2009) argue that there is a 50% chance that the 2°C temperature rise target may not be met when cumulative worldwide CO_2 emissions over the period 2000–2050 are over 1,440 Gt CO_2. At the end of 2010, proven oil, natural gas and coal reserves represented a potential release of 570, 350, and 2300 Gtonne of CO_2, respectively. The current total proven fossil fuel reserves thus represent over 3200 Gt $CO_{2,}$ (WEC, 2010), which cannot be used from a climate perspective without CCS. This is especially true for coal.

CCS contributes to the successful implementation of sustainable energy (Energy-For-B)

This neighbourhood reasons that fossil fuels are needed in the transition period towards a (non-fossil) sustainable energy system. One individual argument points at the need for a backup of fossil power plants to compensate intermittent supply of wind or solar electricity. To reduce CO_2 emissions during this transition period CCS should be applied at fossil power plants. Several authors have proposed a flexible power supply with CCS. Ludig et al. (2011) showed that an electricity system with a large amount of renewable energy combined with fossil fuel power plants equipped with CCS provides a reliable system. Davidson (2009) proposed a system of hydrogen production with CCS for coal gasification with temporary underground hydrogen storage to increase flexibility. The hydrogen will be used in a flexible gas turbine. Meerman et al. (2011) proposed a polygeneration gasification facility with CCS that can produce electricity during peak demands and which switches to production of carbon liquids, methanol and urea during non-peak demands.

CCS requires extra energy (Energy-Against-A)

The only argument in this neighbourhood assumes that (fossil) fuels should be used in an efficient way. The capture part is the most energy intensive part of the CCS chain. The energy needed to capture CO_2 depends mainly on the concentration and pressure of the CO_2 in the gas stream. IPCC (2005) gave a range of the so-called energy penalty for post combustion capture at coal-fired power plants of 24-40%. The CCS energy penalty for new coal-fired power plants based on gasification, or new gas-fired plants is lower (about 19% or 16% respectively according to IPCC (2005). For high concentration CO_2 sources, e.g. from hydrogen and ammonia plants, the CO_2 only has to be compressed. In the proposed Barendrecht case a limited amount of extra energy was needed for the compression and the transport of the CO_2. This would lead to an indirect emission of 5% CO_2 of the total stored CO_2 (Shell, 2008a). The energy penalty thus varies with the type of application. The individual argument that refers to an energy penalty of 10-40%, applies therefore for electricity, steel and chemical industry which produce non pure CO_2 streams.

CCS retards the development of sustainable energy (Energy-Against-B)

This neighbourhood addresses the competition between CCS and renewable energy. This competition is mostly applicable for the generation of electricity, which can also be achieved with solar and wind energy. In several industrial processes where feedstock is needed, e.g. in the steel industry, competition is likely lower, although biomass could be a renewable alternative in this case.

2.5.3. Environment-related arguments

CCS is good for the environment (Environment-For-A)
CCS is bad for the environment (Environment-Against-A)

These neighbourhoods point at the impact of CCS on the environment for non-greenhouse gas emissions. Many studies have conducted Life Cycle Analyses (LCA) of CCS in the power sector (Koornneef, et al., 2008; Singh, et al., 2011; Zapp, et al., 2012). These studies compare the direct and indirect emissions of power plants with and without CCS. The results are similar: almost all emissions, except CO_2, increase with CCS during the whole life cycle. The main cause for extra indirect emissions is the additional energy needed for CO_2 capture. The environmental impact of CCS is therefore greatest in the power sector and other sectors that produce relatively low concentration CO_2 streams. The impact on the local environmental in the vicinity of CCS may vary. For example, direct emissions of SO_2 and particulate matter may be strongly reduced, at the cost of increased emission of ammonia and hydrocarbons (Haskoning, 2011). The impact on the environment is smaller when high concentration CO_2 streams are used. The arguments that CCS is bad for the environment are therefore especially applicable for non-pure CO_2 sources like those of power plants.

2.5.4. Ethics-related arguments

The Netherlands is obliged to store CO_2 (Ethics-pro-A)
The background of this argument is the assumption that CO_2 needs to be stored in order to avoid dangerous climate change. The individual argument specifically refers to CO_2 as a residual product of electricity generation, but may apply to all CCS chains.

CCS is not sustainable (Ethics-against-A)
This neighbourhood labels CCS as unsustainable, as fossil fuel reserves are limited. CCS in combination with biomass as a (renewable) energy source may perhaps be sustainable.

A solution that has little public support is not acceptable. (Ethics-Against-A-3)
The Dutch public is in general not enthusiastic about CCS. However, only 5% to 15% reject CCS, depending on the fuel and application (Paukovic et al. 2011). CO_2 storage at the offshore location K12-B in the Dutch North Sea met no public resistance. However, opposition increases significantly when concrete projects are proposed onshore as seen in Barendrecht (chapter 3). Currently, this generic argument is therefore more applicable to onshore storage projects.

2.5.5. Safety-related arguments

Parts of the CCS chains have proven to be safe (Safety-for-A)
Opponents and advocates of CCS often discuss whether CCS is a proven technology and link this to its safety. Almost all different components of CCS have been applied, although on different scales and circumstances. Only a few complete CCS chains have been demonstrated on industrial scale. It is therefore more useful to discuss the track record of the components, rather than complete chains.

Capture
CO_2 has been captured at industrial processes for almost a century. In most cases this is done to meet process demands and not for storage purposes (IPCC, 2005). Natural gas purification is done on a commercial basis, with various amines solvents that are comparable to those foreseen for post combustion capture. However, the process circumstances for natural gas sweetening are different. That process is under high pressure and with no NO_x or SO_2 present. There have been no applications for CO_2 capture at large-scale power plants of several hundred megawatts. Other gas cleaning technologies for power plants are common practice, for instance for NO_x and SO_2. For the production

of hydrogen, similar processes to pre combustion are widely used and this is considered proven technology. The use of oxy fuel combustion has been demonstrated on pilot scale.

Transport
CO_2 has been transported for decades to EOR projects, mainly in the US and Canada. There is over 2500 km of pipelines transporting CO_2 from natural and industrial sources (IPCC, 2005). The Netherlands has over 200 km of CO_2 pipelines for greenhouses (OCAP, 2007). The experience with CO_2 transport by ship is limited (IPCC, 2005).

Storage
The injection of CO_2 in oil fields for EOR has been done for decades in the US. Apart from the injection in oil fields there are three industrial scale projects operational today, two in Norway and one in Algeria. These projects store CO_2 in deep subsurface aquifers (GCCSI, 2011a). In the Netherlands Gaz de France has been injecting small amounts of CO_2 in an offshore gas reservoir since 2004. Worldwide, there are other smaller storage projects like the Recopol-project where CO_2 is injected in coal layers in Poland.

Concluding, many different components of the CCS chain have been demonstrated on different scales. However, the experience with complete CCS chains in the electricity sector is very limited. The experience and also the occurrence of unexpected situations are thus depending on the specific CCS chain. We classify all four individual arguments as non-generic arguments, as they all refer to a particular part of the CCS chain.

CCS has a positive effect on other safety problems (Safety-For-B)
The individual arguments in this neighbourhood are all applicable for specific CCS chains. The first argument refers to restoring the pressure balance in depleted gas fields, and is thus only applicable to these types of reservoirs. The second argument refers to CCS as an alternative for nuclear energy, and applies to the electricity sector. The third argument refers specifically to coal, as the geographical distribution of coal is larger than for oil and gas (WEC, 2010). For the midterm, the substitution of coal is limited to the power sector as the transport sector is based on oil, whereas heating is based on natural gas. In the long run, one could propose the conversion of coal to liquids and/or gas combined with CCS, making the application broader than the electricity sector.

CCS is unsafe for humans and the environment (Safety-Against-B)

The risks of CCS to humans and the environment are often used as arguments against CCS. We discuss some of these individual arguments in detail.

If CO_2 escapes at a low pressure during transport and storage, it can cause suffocation when there is little wind. (Safety-Against-B-1)

CO_2 can cause suffocation at high concentrations. The impact depends on the duration and concentration of the exposure. For example, concentrations above 10% can cause death when one is exposed for 10 minutes (IEAGHG, 2009). The worst case scenario is a CO_2 blanket that enters a village. An important issue is whether the CO_2 will mix with the air. When CO_2 is released at high pressure it will mix with the air due to its own release velocity. However, when CO_2 is expanded in a closed area, e.g. a tunnel, dangerous concentrations might occur. In the absence of wind, and at the same time the presence of an uneven landscape with hills, ditches et cetera a dangerous CO_2 cloud can be formed. These conditions are mostly applicable for onshore storage.

Post-combustion CO_2 capture can cause emission of carcinogenic substances (Safety-Against-B-4)

The debate on nitrosamines is very technology specific. Nitrosamines are organic, and potentially carcinogenic compounds that can be released during post combustion processes when particular amines are used. Nitrosamines have a short half-life in the atmosphere as they disintegrate after exposure to sunlight. The current debate in the literature focuses on the impact of nitrosamines and the lifetime of nitrosamines (ZEP, 2012).

2.5.6. Economy-related arguments

CCS is good for business and for the creation of skilled employment (Economy-For-A)

Compared to other countries, the Netherlands has a competitive lead in the use of CCS (Economy-For-C)

In this section we discuss these two neighbourhoods together since they both argue that CCS will be beneficial to Dutch economy. The Netherlands has a long tradition on CCS research and is amongst the word leaders in this field (van Egmond et al., 2012), which makes it possible to export knowledge. The Netherlands is also well located for becoming a CO_2 hub. Half of the emissions of large stationary sources in the EU are within a 500 km range. The Netherlands and the neighbouring North Sea, especially the Norwegian waters, have large CO_2 storage capacity. Combined with the long Dutch tradition in gas transport and trading, as well as offshore activities, the Netherlands has a good position to become the CO_2 centre of North West Europe (Platform Nieuw Gas, 2007).

With CCS, climate objectives are economically feasible (Economy-For-B)

The background of this argument is that a low carbon economy is cheaper with CCS than without CCS. ECN (2007) reported that the cost for meeting the Dutch climate goals in 2020 for the whole energy system is € 3.5 billion with CCS versus € 8 billion when CCS is excluded. The scenarios of IEA that reduce CO_2 emissions for the power sector in 2050 by 90% also estimate that excluding CCS will lead to higher electricity prices (IEA, 2010).

CCS costs Dutch business money (Economy-Against-A)
CCS costs Dutch citizens money (Economy-Against-B)

The previous argument stated that a low carbon economy with CCS is less expensive than without CCS. Nonetheless, CCS costs money as well. As capture is the most expensive step of the CCS chain, the cost of CCS will to a large extent be determined by the application. GCCSI (2011b) gives very wide cost ranges.

2.5.7. Overview of applicability of argument towards CCS chains

The applicability of the different CCS chains is summarised in Table 2-1.

	Arguments for			Arguments against			Arguments total		
Theme	All	Spec	Total	All	Spec	Total	All	Spec	Total
Climate	3	4	7	5	2	7	8	6	14
Energy		3	3	1	2	3	1	5	6
Environment		1	1		3	3		4	4
Ethics		1	1	2	1	3	2	2	4
Safety		7	7	5	2	7	5	9	14
Economics	3	4	7	5	3	8	8	7	15
Total	6	20	26	18	13	31	24	33	57

Table 2-1 Applicability of arguments on all respectively specific CCS chains

Twenty-four of the 57 arguments of the map are applicable to all CCS chains. Arguments against CCS are more often generic (18 out of 31), whereas the vast majority arguments in favour of CCS apply for specific chains (20 out of 26). Moreover, only the climate and economics themes have generic pro-arguments, whereas almost all (except environment) arguments against apply to all chains (Table 2-1).

We also analysed arguments addressing specific elements of CCS chains (depicted in Figure 2-2). Ten arguments specifically refer to the fuel source, five of which specifically to coal, four to coal and gas combined and one to biomass. The component application is the most determining factor for specific chains, with 22 references. Fifteen arguments are specifically applicable for electricity production. Four arguments point at the extra energy use due to the capture of CO_2 and refer to non-pure CO_2 sources like power plants and chemical and steel industry. Two specific references to hydrogen production were made, whereas the (steel and chemical) industry was mentioned once.

Four arguments are related to capture technology, of which two regard chemical waste products during post combustion capture. Arguments regarding hydrogen implicitly refer to pre combustion processes (2).

The transportation method was not specifically referred to in the arguments. Arguments regarding storage mainly refer to gas (3) and oil (3) fields. The argument regarding house prices was the only argument specifically referring to onshore storage.

2.6. Discussion and conclusion

In the previous section we have analysed the arguments for and against CCS. It has to be kept in mind that CCS is not one homogeneous technology, which hampers drawing generalised conclusions. We conclude that most of the arguments have been phrased in such a way that they apply to specific configurations only. Nonetheless, with different wording several of these arguments may be applicable in a more generic way. For example, the argument 'CO_2 is a residual product of electricity generation, which should not be discharged into the atmosphere', only applies to the electricity section, but is in fact related to all emitted CO_2, with perhaps biomass as the only exception.

Some arguments are perceived as stronger and more relevant than others. However, it is almost impossible to rank the arguments, since the importance of an argument differs from one person to the other. For example, the argument 'CCS retards the development of sustainable energy' is crucial for people who want to end the fossil era as quickly as possible. This is an irrelevant argument for those who are of the opinion that climate and environmental targets should be met, regardless the route.

The presented categorization of arguments and their scope may contribute to a better-informed debate. However, we realise that the presented arguments are still rather technical and may be far away from the perception of a local resident near a storage location, as some social issues of the debate (e.g. NIMBY) have not been taken into account. As such, the map presented here is therefore especially useful for the CCS community and policy makers as a tool to improve techno-economical considerations on future energy systems.

3. The views of the public on CCS[1]

3.1. Introduction

Mitigation of climate change requires substantial modification of current patterns of energy production and consumption. Despite promising developments in the field of renewable energy, fossil fuel consumption is increasing and carbon-intensive industries continue to be prominent. Carbon Capture and Storage (CCS) may be an important component in a portfolio of approaches to climate change mitigation (IPCC, 2014). If CCS is to become a viable option policy makers and industry must encourage its development (IEA, 2013b; Scott et al., 2013). Among the general population there is little support for CCS (Upham and Roberts, 2011; de Best-Waldhober et al., 2012b; L'Orange Seigo et al., 2014), and this discourages stakeholders from moving towards large-scale implementation (Wüstenhagen et al., 2007; Markusson et al., 2012a). Progress towards broad support requires pro-active communication between stakeholders and the public (Ashworth et al., 2010), but communication efforts are hampered by a lack of understanding of how citizens react to information provided by proponents and opponents of CCS (Reiner, 2008).

Existing guidelines for communication primarily deal with the process of communication rather than the content of the message (Wüstenhagen et al., 2007; Brunsting et al., 2011b). Research shows that only presenting sound scientific information is unlikely to increase support, and messages are more likely to have an effect if they resonate with the values of citizens (Kahan, 2010; Kahan et al., 2012). It is still largely unknown which arguments for or against CCS influence public opinion. For instance, proponents often assume that pro-CCS arguments should take the form of presenting the dangers of climate change and the benefits of mitigating CO_2 emissions, but there is currently no empirical evidence supporting this assumption. A systematic investigation of how citizens evaluate arguments for and against CCS is important to improve understanding of the effect of communication on citizens' attitudes towards CCS.

---

[1] This chapter is adapted from: K.P.F. Broecks, S. van Egmond, F.J. van Rijnsoever, M. Verlinde-van den Berg, M.P. Hekkert, Persuasiveness, importance and novelty of arguments about Carbon Capture and Storage, Environmental Science & Policy, Volume 59, May 2016, Pages 58-66.

Any such investigation should go beyond simply documenting the persuasiveness of the various arguments if it is to really improve understanding of public opinion. Dual processing models suggest that individuals must be motivated and have knowledge about the topic in order to process information in depth (Petty and Wegener,1999; Chen and Chaiken, 1999). This implies that unimportant or new arguments will not be considered, as they are likely to activate cognitive shortcuts and emotions, which usually leads to unstable opinions (Petty and Wegener,1999; Chen and Chaiken, 1999). A communicator attempting to encourage the audience to adopt a specific stable opinion should select arguments that are perceived as *persuasive*, *important* and are not completely *novel* to the audience. An investigation should also avoid making unrealistic assumptions about the homogeneity of the population (Allenby and Rossi, 1999). Arguments that are not generally important might be significant for a particular segment of the population. Establishing how the opinions of these segments differ from the general opinion is therefore also important.

We determined the persuasiveness, importance and novelty of 16 arguments for and 16 arguments against CCS in specific segments of the Dutch population. The arguments related to topics such as climate change, risks to human welfare, the impact of CCS on the energy production system, and effects on electricity prices and economic growth. We used a discrete choice experiment in which respondents were required to choose which of a pair of pro or con arguments was the most persuasive, the most important or the newest in consecutive choice sets.

3.2. Methods

3.2.1. Argument selection

Arguments were selected from the Argument map that is described in chapter 2 (see also van Egmond and Hekkert, 2012). To reduce the number of arguments from 57 to 32 we identified which group of arguments could be represented satisfactorily by their overarching argument category in the Argument map. Several arguments were omitted because they were too complex to be presented in one or two sentences. Our selection process was informed by a media analysis and studies of common misconceptions about CO_2 or CCS (de Best-Waldhober et al., 2012a; Wallquist et al., 2010). We also held a review session with experts from academia, knowledge institutes and industry to discuss the selection of arguments. See Table 3-1 for the arguments. The survey was held in Dutch. An English translation of the arguments is presented in Table 3-1.

3.2.2. Discrete choice experiment.

There were two separate experiments, one for the pro arguments and one for the con arguments. A full factorial design was used, which entails that every combination of two arguments was included in the experiment (240 choice sets). The choice sets were divided into 30 blocks to reduce the number of choice sets per respondent to eight. Each choice set contained three questions, namely 'which argument do you find most persuasive / important / new?'. See Figure 3-1 for an example choice set.

Message 1	Message 2
A waste product such as CO_2 should be disposed of properly.	CO_2-storage can be used in industries where no other options for CO_2-reduction exist.
Which of the two messages…	
…..do you think is most persuasive?	
□ Message 1	□ Message 2
…..do you think is most important?	
□ Message 1	□ Message 2
….. is most new to you?	
□ Message 1	□ Message 2

Figure 3-1 Example choice set of two pro CCS arguments

Number	Description argument pro (P) CCS
P1	The climate problem cannot be solved without CO_2 storage.
P2	CO_2 storage is needed to honor international climate agreements.
P3	CO_2 storage requires few lifestyle changes.
P4	The Netherlands should set an example when it comes to CO_2 storage.
P5	CO_2 storage reduces the need for nuclear energy.
P6	CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions.
P7	CO_2 storage makes it feasible to use large supplies of coal for cheap energy.
P8	The development of technology for CO_2 storage contributes to employment and economic growth.
P9	CO_2 storage is cheaper than solar or wind energy in the medium to long term.
P10	The Netherlands has a good starting position because of its experience with natural gas.
P11	Other countries have used technologies for CO_2 storage safely for many years.
P12	CO_2 storage is already being used to recover more oil from oilfields.
P13	CO_2 storage is safe. CO_2 is stored in natural gas fields where natural gas was stored for millions of years.
P14	CO_2 storage uses less space than solar panels or wind turbines.
P15	Gas or coal plants with CO_2 storage are a stable supplement to the inconsistent supply of solar and wind energy.
P16	A waste product such as CO_2 should be disposed of properly.

Number	Description Argument con (C) CCS
C1	The climate problem can be tackled without CO_2 storage.
C2	CO_2 storage promotes the use of new coal-fired power plants.
C3	CO_2 storage is more expensive than solar or wind energy in the long term.
C4	It is not certain that there will be a return on large investments in CO_2 storage.
C5	Storage sites for CO_2 have to be monitored indefinitely.
C6	Real estate prices near CO_2 storage facilities may fall.
C7	CO_2 storage detracts from the development of renewable energy.
C8	Electricity bills will rise because of CO_2 storage.
C9	CO_2 storage is new and has never been applied on a large-scale, so the risks are not fully understood.
C10	It is better to avoid generating CO_2 than to store the CO_2.
C11	If a lot of CO_2 leaks on a windless day, a suffocating cloud of CO_2 could be created.
C12	Groundwater might become acidified if CO_2 were to leak out of an underground pipeline.
C13	CO_2 storage can cause small earthquakes, comparable to those caused by natural gas extraction.
C14	Hazardous chemicals are used in the capture of CO_2.
C15	Power plants with CO_2 storage require 10-40 % more energy.
C16	There is little public support for CO_2 storage.

Table 3-1 Arguments used in favour or against CCS. The term 'CO_2 storage' and not CCS was used in these arguments, as this is the term more commonly used by the Dutch media.

3.2.3. Measurement of attitude change.

Before and after the choice experiment, respondents were asked to indicate their attitude towards CCS by completing three items using a five-point Likert scale ('totally disagree' to 'totally agree'): 'I am positive about CO_2 storage', 'CO_2 storage is dangerous', and 'CO_2 storage is useful'. Scores for the three items were averaged to give a score that indicated attitude towards CCS. The reliability of the attitude scale was adequate (Cronbach's α; before=0.76, after=0.81).

3.2.4. Sample and data collection.

Data were collected from a sample of members of a national online marketing panel in the Netherlands (n=920). The survey was held in the summer of 2012. Quotas for age and gender were used to ensure that the sample was representative of the adult Dutch population (> 18 years). Panel members received compensation for their participation, they were assured of the anonymity of the results and they were debriefed at the end of the survey. The mean age of respondents was 51.7 years (SD=13.4) and 53.4 % of the sample was female. Respondents were randomly assigned to one of two experimental groups and to a survey version. The first group read pro arguments (n = 465) and the second group read con arguments (n = 455).

Before answering the questions, the respondents got a short explanation on CCS: 'With CCS CO_2 is captured from a location where large amounts of CO_2 are produced, for example a power plant. Subsequently CO_2 is transported to a location where it is stored in the subsurface for an extended period of time. The aim of CCS is to avoid that CO_2 is emitted into the atmosphere'.

3.2.5. Model specification and selection.

Two types of models were estimated using the software package Latent Gold 4.5; mixed logit models (Layton, 2000) and latent class models (Vermunt and Magidson, 2002). Separate models for persuasiveness, importance and novelty were estimated using choice as a binary dependent variable. The arguments were included as independent variables so the estimators indicated the utility respondents assigned to each argument. The utility of one argument was constrained to zero to allow the models to be estimated. The position of the arguments in the choice set (left or right) was added as a control variable. We accounted for differences in respondent consistency by estimating scale classes

(Swait and Louviere, 1993). We explored solutions consisting of one to four latent classes and one to two scale classes. The Bayesian Information Criterion (BIC) was used to determine the optimal solution (Nylund et al., 2007).

3.3. Results

3.3.1. Attitude change

We tested whether the range of arguments to which an individual was exposed had any effect on attitude towards CCS. Before exposure to the arguments the average attitude score was neutral ($M=2.98$, $SD=0.76$). Attitudes changed significantly after exposure to pro arguments ($M=3.18$, $SD=0.76$, $p<0.001$) and con arguments ($M=2.71$, $SD=0.75$, $p<0.001$). This implies that participating in the choice experiment had a small, but significant effect on attitude towards CCS.

3.3.2. Mixed logit models

With regard to the pro CCS arguments we found that argument P6 ('CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions') was the most persuasive (71% of the cases). The argument 'CO_2 storage requires few lifestyle changes' (P3) was the least frequent chosen argument (29%).

A more in-depth analysis was performed with mixed logit models where the parameters represent general opinions (McFadden R^2 = 0.11-0.19, see Table 3-2). Arguments presented on the left side of the survey were chosen more frequently than arguments on the right side, which was corrected for in the models. The mixed logit models revealed a strong *positive* correlation between the estimators of persuasiveness and importance (pro: $\rho=0.91$ and con: $\rho=0.98$) and a moderate *negative* correlation between the estimators of persuasiveness and newness (pro: $\rho= -0.29$ and con: $\rho= -0.65$). This entails that important arguments are likely to be persuasive and vice versa, but that new arguments are likely to be unpersuasive. New and unpersuasive arguments included those that discussed the extra energy that CCS would require (C15), the use of hazardous chemicals (C14) and enhanced oil recovery (P12).

The results show that the most persuasive *and* most important pro arguments did not contain any reference to climate change. Important and persuasive arguments were focused instead on the application of CCS in carbon-intensive industries (P6), the analogy between CO_2 and other waste products (P16), the safety of storage in natural gas fields (P13) and the economic opportunities created by CCS (P8). This implies that citizens appreciate a discussion that encompasses more than the topic of climate change mitigation. They are more likely to engage with communication materials that include analogies to current practices and insight into the opportunities created by CCS.

A more general finding is that arguments that appeal to personal norms are relatively persuasive and important. The second most persuasive argument (P16) was an appeal to such a norm, 'waste should be disposed of properly'. Similarly, the most persuasive and important con argument (C10) appeals to another norm, that prevention (of CO_2 production) is better than a cure (CCS). Appeals to norms are persuasive (Bamberg and Möser, 2007; De Groot and Steg, 2010), often more so than purely factual arguments, especially if they resonate with the norms and values of the audience (Kahan, 2010).

The other most persuasive and important con arguments refer to the lack of understanding of the risks of CCS (C9), the ability to tackle climate change without CCS (C1), the high costs of CCS (C3) and the need for indefinite monitoring (C5). Overall, citizens chose these arguments above arguments that discuss *specific* risks, such as earthquakes, leakage or falling of real estate prices. An overview of the outcomes is given in Table 3-2.

	Pro				Con		
	Persuasive	Important	New		Persuasive	Important	New
P1	9	5	16	C1	**3**	**3**	14
P2	6	7	15	C2	16	16	10
P3	16	16	8	C3	5	4	7
P4	14	12	13	C4	7	9	11
P5	8	6	7	C5	4	5	12
P6	**1**	**2**	10	C6	12	14	13
P7	13	11	4	C7	11	7	6
P8	4	**3**	9	C8	15	15	8
P9	11	10	**2**	C9	**2**	**2**	9
P10	5	8	12	C10	**1**	**1**	16
P11	10	13	3	C11	6	8	**3**
P12	12	15	**1**	C12	9	6	5
P13	**3**	4	11	C13	10	11	4
P14	15	14	5	C14	13	10	**1**
P15	7	9	6	C15	14	13	**2**
P16	**2**	**1**	14	C16	8	12	15

Table 3-2 Relative ranking of arguments in mixed logit models; 1 indicates that the argument was most frequently chosen, whereas 16 was the least frequent chosen argument. When arguments scored equal, the same ranking is given. See Table 3-5 for more details. The top 3 arguments are indicated in bold.

3.3.3. Latent class models

Latent class models provide insight into differences between segments for each subset of respondents. We made a cluster analysis based on the choice for persuasiveness of the arguments. The group that was exposed to pro arguments could be divided into 3 segments of similar size, whereas 2 segments that differed significantly from each other could be identified for the respondents that were exposed to con arguments. Different segments are indicated by a number, exposure to Pro or Con arguments of CCS (see Table 3-3 and Table 3-4). The demographic composition of the segments was relatively similar.

	Pro-1 34%	**Pro-2 34%**	**Pro-3 32%**		**Con-1 82%**	**Con-2 18%**
P1	12	**2**	10	C1	**3**	6
P2	**3**	**3**	15	C2	16	11
P3	9	16	14	C3	4	9
P4	15	10	16	C4	7	10
P5	11	12	**3**	C5	4	8
P6	**1**	4	**1**	C6	13	4
P7	16	10	5	C7	7	11
P8	4	5	9	C8	15	7
P9	10	9	7	C9	**2**	**3**
P10	6	7	13	C10	**1**	5
P11	5	13	8	C11	11	**2**
P12	8	15	6	C12	7	13
P13	7	6	**2**	C13	13	**1**
P14	13	14	12	C14	11	14
P15	14	8	4	C15	10	16
P16	**1**	**1**	11	C16	4	15

Table 3-3 Relative ranking of arguments in latent class models for persuasiveness; 1 indicates that the argument was most frequently chosen, whereas 16 was the least frequent chosen argument. When arguments scored equal, the same ranking is given. See Table 3-6 for more details. The top 3 arguments are indicated in bold. Percentages indicate the size of the different segments.

Rank	Argument	
	Segment Pro-1 (34%)	
1	P16	A waste product such as CO_2 should be disposed of properly.
2	P6	CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions.
3	P2	CO_2 storage is needed to honor international climate agreements.
	Segment Pro-2 (34%)	
1	P16	A waste product such as CO_2 should be disposed of properly.
2	P1	The climate problem cannot be solved without CO_2 storage.
3	P2	CO_2 storage is needed to honor international climate agreements.
	Segment Pro-3 (32%)	
1	P6	CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions.
2	P13	CO_2 storage is safe. CO_2 is stored in natural gas fields where natural gas was stored for millions of years.
3	P5	CO_2 storage reduces the need for nuclear energy.
	Segment Con-1 (82%)	
1	C10	It is better to avoid generating CO_2 than to store the CO_2.
2	C9	CO_2 storage is new and has never been applied on a large-scale, so the risks are not fully understood.
3	C1	The climate problem can be tackled without CO_2 storage.
	Segment Con-2 (18%)	
1	C13	CO_2 storage can cause small earthquakes, comparable to those caused by natural gas extraction.
2	C11	If a lot of CO_2 leaks on a windless day, a suffocating cloud of CO_2 could be created.
3	C9	CO_2 storage is new and has never been applied on a large-scale, so the risks are not fully understood.

Table 3-4 Top 3 ranking of arguments in latent class models for persuasiveness of the different Pro and Con segments.

The differences between the Pro segments are relatively small. Segments Pro-1 and Pro-2 prefer more moral arguments as they consider P16 ('A waste product such as CO_2 should be disposed of properly'), and P2 ('CO_2 storage is needed to honour international climate agreements') persuasive. However, Pro-2 also includes the climate change argument P1 ('The climate problem cannot be solved without CO_2 storage'), suggesting that this group is more open to climate change arguments. Pro-3 is most responsive to pragmatic arguments (P6; CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions, P13; 'CO_2 storage is safe. CO_2 is stored in natural gas fields where natural gas was stored for millions of years', P5; 'CO_2 storage reduces the need for nuclear energy').

The majority of the respondents that have been exposed to Con arguments find C10 ('It is better to avoid generating CO_2 than to store the CO_2'), C9 ('CO_2 storage is new and has never been applied on a large-scale, so the risks are not fully understood') and C1 ('The climate problem can be tackled without CO_2 storage') most persuasive. Based on their choices the respondents can be subdivided in two segments (Con-1 and Con-2). Segment Con-1 is the largest group (82%) that consider C10 by far the most important argument, whereas other con arguments are perceived as more or less equally persuasive. There was a small segment Con-2 (18%) that chose arguments about risks and hazards as top 3 most persuasive arguments (C13; 'CO_2 storage can cause small earthquakes, comparable to those caused by natural gas extraction', C11; 'if a lot of CO_2 leaks on a windless day, a suffocating cloud of CO_2 could be created', C9; 'CO_2 storage is new and has never been applied on a large-scale, so the risks are not fully understood').

The risks of CCS are communicated through terms that inspire fear or anxiety, such as 'suffocation' or 'earthquakes'. The uncertainty about the consequences of CCS and the potential for catastrophe can inspire dread in an audience (Slovic et al., 2007). The emotions that are generated in this way can be an important factor in decision making (Slovic et al., 2007). Interestingly, the results of the latent class models show that these arguments are persuasive for a (minority) segment of the population, whereas this cannot be concluded from the mixed logit analyses.

3.4. Conclusions and future directions

This study has systematically identified how citizens evaluate arguments in favour or against CCS. The goal was to advance understanding of how citizens respond to the content of communications materials. The results have identified the persuasiveness, importance and novelty of these arguments and have shown that involving citizens in an evaluation of arguments can affect their attitude towards CCS. Although the primary goal of CCS is climate change mitigation, most citizens find arguments about climate change relatively unpersuasive. They instead find arguments about norms and values or arguments about additional opportunities and benefits, such as industrial applications of CCS and effects on employment and economic growth, more persuasive. There is heterogeneity for the preference of arguments within the population. For example, some citizens do find arguments about climate change persuasive (segment Pro-2; 34%). A communicator may be able to engage these citizens sufficiently with a focus on climate change mitigation. Other citizens prefer arguments that focus on the utility of CCS (segment Pro-3; 32%). These citizens are more likely to engage with communications materials that focus on the role of CCS within a portfolio of energy technologies. The results for con arguments show a significant amount of heterogeneity, as 18% of respondents were open for arguments relating to risks. For 82% of the respondents 'prevention of CO_2 emission rather than storing it' was deemed most persuasive. Accounting for such differences between segments of citizens is key to the design of CCS communication materials. The separation in segments was based on the choice between the arguments. The demographic composition of the segments was relatively similar. As such, it is difficult to develop communication strategies to reach specific segments. Nonetheless, we showed that it is possible to influence attitude towards CCS by exposure to pro or con arguments. Respondents who read con arguments were slightly more susceptible to attitude change, which is in line with previous findings as negative information often attracts more attention than positive information (Skowronski and Carlston, 1987; Cobb and Kuklinski, 1997).

Climate change mitigation is the primary goal of CCS. Our study, however, implies that it will be difficult to get the importance of CCS across without embedding the technology in a broader discussion, including e.g. industrial applications, energy security and affordability. This does not suggest that stakeholders should misrepresent the value of CCS by focusing primarily on additional benefits. Rather, it calls attention to the discrepancy between the primary goal of CCS and the preferences of citizens for other arguments and issues. As citizens also find arguments that appeal to norms more persuasive, a valuable strategy for engaging them may be to use norms and values in arguments about climate change.

Two limitations of this study are issues for further research. First, we examined arguments in isolation. Our analysis did not attempt to account for interactions between the source of the message and the nature of the message (Eagly et al.,1978), different frames (Bickerstaff et al., 2008; Meyerowitz and Chaiken, 1987) or the influence of other content. Future studies could extend the analysis to encompass full messages, with different sources and frames. Second, this study focused on a single country, which limits the generalizability of the results. The importance of norms or values and the perceived relevance of climate change vary across countries and cultures. Future research should include between-country comparisons of the influence of arguments on attitude towards CCS.

3.A. Annex: detailed results of mixed logit and latent class models

	Pro				Con		
	Persuasive	Important	New		Persuasive	Important	New
R^2	0.11	0.15	0.17		0.17	0.19	0.18
P1	-0.63 (0.18)*	-0.44 (0.13)*	-0.22 (0.41)	C1	1.14 (0.40)*	1.79 (0.40)*	0.48 (0.29)
P2	-0.36 (0.18)*	-0.63 (0.13)*	-0.08 (0.40)	C2	-1.50 (0.53)*	-0.97 (0.56)	1.08 (0.35)*
P3	-1.53 (0.19)*	-1.54 (0.15)*	1.45 (0.43)*	C3	0.31 (0.32)	0.93 (0.40)*	1.27 (0.33)*
P4	-1.25 (0.17)*	-1.11 (0.12)*	0.50 (0.48)	C4	0.03 (0.33)	0.10 (0.36)	1.03 (0.31)*
P5	-0.59 (0.19)*	-0.59 (0.13)*	1.49 (0.49)*	C5	0.42 (0.34)	0.87 (0.35)*	0.83 (0.35)*
P6	0.28 (0.18)	-0.04 (0.07)	1.05 (0.51)*	C6	-0.37 (0.37)	-0.76 (0.55)	0.64 (0.32)*
P7	-1.12 (0.19)*	-1.10 (0.12)*	1.70 (0.42)*	C7	-0.31 (0.39)	0.70 (0.42)	1.33 (0.32)*
P8	-0.19 (0.18)	-0.20 (0.12)	1.28 (0.45)*	C8	-0.90 (0.41)*	-0.93 (0.63)	1.18 (0.30)*
P9	-0.73 (0.18)*	-1.01 (0.14)*	2.27 (0.53)*	C9	2.30 (0.59)*	1.88 (0.42)*	1.09 (0.39)*
P10	-0.33 (0.18)	-0.71 (0.13)*	0.89 (0.50)	C10	6.82 (3.91)	6.46 (4.22)	-0.28 (0.29)
P11	-0.69 (0.19)*	-1.15 (0.12)*	1.91 (0.54)*	C11	0.07 (0.43)	0.61 (0.39)	1.91 (0.35)*
P12	-1.10 (0.19)*	-1.35 (0.13)*	2.56 (0.65)*	C12	-0.06 (0.39)	0.83 (0.41)*	1.49 (0.34)*
P13	-0.06 (0.18)	-0.29 (0.12)*	1.00 (0.47)*	C13	-0.30 (0.35)	0.04 (0.39)	1.59 (0.37)*
P14	-1.27 (0.19)*	-1.22 (0.13)*	1.59 (0.49)*	C14	-0.49 (0.39)	0.06 (0.40)	2.65 (0.36)*
P15	-0.46 (0.18)*	-0.86 (0.15)*	1.56 (0.49)*	C15	-0.71 (0.30)*	-0.47 (0.33)	1.94 (0.29)*
P16	Constrained to zero			C16	Constrained to zero		

Table 3-5 Mixed logit models. The table displays parameter estimates, and standard errors. Significance level is indicated by asterisks (* p<0.05). Significance of an argument indicates that persuasiveness, importance or novelty is significantly different from the reference argument (P16 / C16).

Pro (R^2=0.37)				Con (R^2=0.28)		
	PP 1 (34.2%)	**PP 2 (34.0%)**	**PP 3 (31.8%)**		**CP 1 (81.2%)**	**CP 2 (18.2%)**
P1	-1.27 (0.23)*	-0.32 (0.47)	0.05 (0.11)	**C1**	0.05 (0.02)*	0.60 (0.22)*
P2	-0.11 (0.07)	-0.37 (0.47)	-0.25 (0.15)	**C2**	-0.11 (0.04)*	0.23 (0.11)*
P3	-1.14 (0.23)*	-3.94 (1.13)*	-0.13 (0.08)	**C3**	0.00 (0.02)	0.51 (0.17)*
P4	-1.46 (0.22)*	-1.13 (0.48)*	-1.01 (0.37)*	**C4**	-0.02 (0.02)	0.50 (0.17)*
P5	-1.26 (0.23)*	-1.27 (0.48)*	0.93 (0.25)*	**C5**	0.00 (0.02)	0.55 (0.15)*
P6	0.00 (0.05)	-0.43 (0.47)	1.23 (0.42)*	**C6**	-0.06 (0.02)*	1.66 (0.47)*
P7	-3.03 (0.79)*	-1.13 (0.48)*	0.74 (0.25)*	**C7**	-0.02 (0.02)	0.23 (0.13)
P8	-0.45 (0.36)	-0.46 (0.47)	0.25 (0.27)	**C8**	-0.08 (0.02)*	0.59 (0.24)*
P9	-1.22 (0.23)*	-1.08 (0.49)*	0.50 (0.29)	**C9**	0.08 (0.03)*	1.82 (0.47)*
P10	-0.48 (0.36)	-0.58 (0.48)	-0.03 (0.05)	**C10**	0.60 (0.27)*	1.58 (0.48)*
P11	-0.46 (0.36)	-1.39 (0.50)*	0.37 (0.29)	**C11**	-0.04 (0.03)	1.95 (0.49)*
P12	-1.02 (0.23)*	-2.59 (0.60)*	0.59 (0.28)*	**C12**	-0.02 (0.02)	0.16 (0.10)
P13	-0.50 (0.36)	-0.54 (0.47)	0.95 (0.26)*	**C13**	-0.06 (0.02)*	2.15 (0.50)*
P14	-1.34 (0.23)*	-1.46 (0.50)*	-0.01 (0.07)	**C14**	-0.04 (0.02)	0.14 (0.12)
P15	-1.38 (0.23)*	-0.68 (0.47)	0.87 (0.26)*	**C15**	-0.03 (0.02)	1.09 (1.53)
P16	Constrained to zero			**C16**	Constrained to zero	

Table 3-6 Latent class models for persuasiveness of arguments. The table displays parameter estimates and standard errors. Significance is indicated by asterisks(* $p<0.05$). Significance of a parameter (z-test) indicates that persuasiveness of an argument is significantly different from the reference argument (P16/C16).

4. The political debate on CCS

4.1. Introduction

CO_2 capture and storage (CCS) is a configuration of technologies that capture CO_2 from the exhaust gases of power plants or large industrial facilities, subsequently transports CO_2 to a storage location and then stores CO_2 in the deep subsurface in depleted gas fields or aquifers. CCS is identified by many energy scenarios as an important technology to reduce CO_2 emissions in order to avoid dangerous climate change (e.g. IEA, 2013a; WEC, 2013). However, the actual implementation of CCS is advancing slowly (Scott et al., 2013). Many studies try to find an explanation for this slow progress. Several of these studies address the lack of economic incentives for industry to implement CCS (de Coninck et al., 2009; van Alphen et al., 2010; IEA, 2013b). Others point at local opposition as a reason for the slow implementation (Huijts et al., 2007; Shackley et al., 2009). Multiple studies have been performed to investigate public acceptance of local CCS projects, and provided recommendations to influence public opinion. Poor communication, distrust of the project developer, lack of public engagement, the perceived local impact, a relatively unknown technology and the absence of benefits for the local population are seen as important factors that explain local opposition (Ashworth et al., 2012; Markusson et al., 2011; Oltra et al., 2012, Terwel, 2008). In the previous chapter (Chapter. 2) we investigated the persuasiveness, importance and novelty of arguments to the general public.

Political considerations and willingness of governments to increase policy efforts to develop and implement CCS technology received relatively little attention, as studies on CCS policy focus on the description of existing policies (Meadowcroft and Langhelle, 2011; Pollak et al., 2011) or effects of new policy instruments (Groenenberg and de Coninck, 2008; Schumacher and Sands, 2006). However, without strong political support, chances of successful CCS implementation are slim. According to the International Energy Agency (2013b) commitment of governments is therefore needed.

CCS experiences difficulties to gain general acceptance. Contrary to renewable energy, it does not prevent carbon emissions, but captures carbon that leaves the exhaust pipe of power plants or industrial facilities and stores it in the subsurface. Furthermore, CCS does not fit in the ‘small is beautiful’ frame of decentralised energy production based on renewables. CCS is a technology that fits best with centralised energy production and large sources of CO_2. On top of this, some people question the safety of subsurface storage. Not surprisingly, most surveys that investigated the attitude of the general public show reluctance to accept CCS as a climate mitigation option. Nonetheless, CCS is not outright rejected either, although renewable energy is preferred (e.g. Tokushige et al., 2007; Shackley et al., 2007; Oltra et al., 2010; Upham and Roberts, 2011; de Best-Waldhober et al., 2009).

It is essential to formulate the right message, which needs to be well aligned with existing values in society and relate to problems that are considered important by societal actors. Therefore, it is important to learn how the characteristics of CCS resonate with the ideas and visions of different groups in society.

Studying the political debate on CCS is a useful way to create insight in the societal debate regarding CCS, also because politicians represent different voter groups. Moreover, their debates are often based on arguments and are perfectly recorded and traceable in archives. So, the political debate regarding CCS may provide insights in how CCS is perceived by different groups in society and what arguments are used for underpinning their position. This type of research has not yet been performed.

We selected the Dutch political system for our study on CSS considerations of politicians, because of two reasons. First, the Netherlands has a multi-party system. On average approximately ten parties are represented in Parliament (Andeweg and Irwin, 2009). The political ideologies of these parties are well described, which makes it possible to compare opinions on CCS with general political viewpoints and traditions. Second, CCS has a long track record in the Netherlands, as first plans for a demonstration project were proposed in the early nineties (van Egmond et al., 2012). Hence, much data on argumentation in Parliament is available.

In this study we analysed the views of the different Dutch political parties on CCS, and examined the underlying arguments that underpin these opinions. We investigated the positions on CCS in relationship with the overall standpoint on climate change. As CCS is a climate mitigation technology we hypothesise that strong climate ambitions facilitate acceptance of CCS. Additionally, the political ideology ranging from left to right standpoints as well as progressive versus conservative views have been taken into account.

In this chapter we give a short background on CCS and the political system in the Netherlands. In section 4.3 we describe our method. The sections 4.4 - 4.6 describe the results, including the link between climate positions and standpoints regarding CCS. The chapter is ended with conclusions and a discussion (4.7).

4.2. Background on CCS and Dutch politics

4.2.1. Development of CCS in the Netherlands

The first concrete ideas on CO_2 storage arose almost 25 years ago when the first memorandum on climate change was presented by the Dutch government (Environmental Affairs, 1991). In this policy paper a possible contribution of CCS of 4 to 6.5 Megatonne CO_2 reduction per year was foreseen in the period after 2000, which constituted approximately 3% of the Dutch CO_2 emissions. As a result the government announced in 1992 that it intended to develop a CCS demonstration project together with the Dutch electricity producers (Economic Affairs, 1992).

Subsequently, multiple governmental memorandums have pointed at the importance and possibilities of CCS for the longer term, and several other demonstration projects have been proposed. However, the actual realisation of CCS projects in the Netherlands is limited. A small offshore CO_2 storage project by Gaz de France and a project by Shell to supply greenhouses with CO_2 were realised in 2005. Furthermore, three capture pilot projects were accomplished (ECN in 2007, Maasvlakte in 2008, Buggenum in 2010). In 2007 the national government tendered for two CO_2 storage demonstration projects with a payment of € 30 million each. One of the projects that was chosen by the government was the storage of CO_2 from an ammonia plant in the subsurface under the same industrial area. However, this project was cancelled due to financial issues. The other awarded project was the Barendrecht storage project of Shell. In this project CO_2, produced by a nearby refinery, would be captured and stored under the small city of Barendrecht. Over time, local opposition increased and the necessity of this project and the concept of CCS were heavily debated in the national Parliament, which ultimately led to cancellation of the project (van Egmond and Hekkert, 2015/ chapter 6).

Thus, from 1990 onwards the Dutch government had an interest in CCS as a climate mitigation option. The different governments in time all agreed to a certain extent that CCS would be necessary in the long run.

However, the urgency for undertaking concrete short term activities fluctuated strongly over the years. The governmental interest in supporting pilot and demonstrations projects peaked in the period between 2005 and 2010, which was reflected in terms of available budget.

4.2.2. Dutch political system[1]

The Dutch national political debate is mostly held in the so called 'Second Chamber', which is, for reasons of simplicity, referred to as Parliament in this paper. The Parliament consists of multiple political parties that are proportionally represented based on the number of nationwide votes. The Cabinet is composed of Ministers and comprised of a coalition of two or more parties. The government's policy programme is therefore a result of inherent coalition negotiations and compromises.

It is important to note that Ministers cannot be Members of Parliament, which illustrates the dualism of the Dutch political system where Parliament and Cabinet have distinct roles and responsibilities. The vast majority of new bills and policy documents originate from the Cabinet. During the reading Members of Parliament may request adaptations in Cabinet policy. After several rounds of deliberation the Parliament takes a final vote on the bill, which is subsequently executed by the Cabinet. The Minister of Economic Affairs is accountable for energy policy, whereas the Minister of Environmental Affairs is responsible for climate change mitigation. The policy on CCS is thus a combined responsibility of both Ministers, which can be members of different parties in Cabinet. As such, also CCS policy may be subjected to compromise.

4.3. Method

4.3.1. Dutch political parties

Since Parliament consists of over 10 parties, analyses are greatly facilitated by clustering political parties, which can be done based on ideologies, religion, organisation of the party, ethnicity etc. (Gunther and Diamond, 2003). One of the most commonly used methods is a left wing to right wing separation (Deschouwer and Hooghe, 2011). Due to the establishment of several new parties in the Netherlands, it was

1 This section is adapted from text books on the Dutch political system (Andeweg and Irwin, 2009; Bovend'Eert & Kummeling, 2010)

necessary to add a second division that ranges from progressive to conservative (Kieskompas.nl, 2014). We use the latter model, as this incorporates the Dutch political parties during multiple elections.

The Dutch Voter Advice Application (Kieskompas.nl, 2014) was developed by political scientists from the VU University Amsterdam. This tool divides parties in Parliament in a graph with two political dimensions in order to compare their political positions (Wall et al., 2012). On the horizontal axis the classic left-right dimension is used (Figure 4-1). Left parties see a role for the government to redistribute financial wealth, whereas parties on the right side of the political spectrum prefer a limited role for government policy and favour market mechanisms for the distribution of resources. The vertical axis depicts the dimension ranging from progressive to conservative. The Dutch Voter Advice Application has defined progressive parties as more open to a multicultural society and in favour of individual rights like gay marriage, abortion and euthanasia. In contrast, conservative parties opt for a more nationalistic and monoculture society and value traditional families and religion. Furthermore, progressive parties favour the environment over economy when dilemmas on economic and environmental issues arise, whereas conservative parties tend to value economic arguments more (Kieskompas, 2014).

The Dutch political landscape consists of several left progressive and right conservative parties. Only one right progressive party and no left conservative party are represented in Parliament. Two conservative parties are neither left nor right-wing.

The Christian democrats (CDA) is the largest Christian party and has a long tradition in governing the Netherlands[1]. Two smaller conservative Christian parties (CU and SGP) are also represented in Parliament. Within the liberal family two parties are represented in Parliament, referred to as the conservative liberals (VVD) and the progressive liberals (D66). On the left side the Labour Party (PvdA), the Socialists (SP), the Greens (GL) and the Party for the Animals (PvdD) are represented, but of these only the PvdA has been in administrative power. The PvdD has been established recently, and focuses on a green agenda. The freedom party (PVV) registered as a political party in 2006, and has an anti-EU as well as an anti-Islam agenda (Otjes and Louwerse, 2015).

1 The descriptions of the parties are based on (Andeweg and Irwin, 2009). In Annex 5.A., a table with the parties and their number of seats in Parliament are presented in percentages.

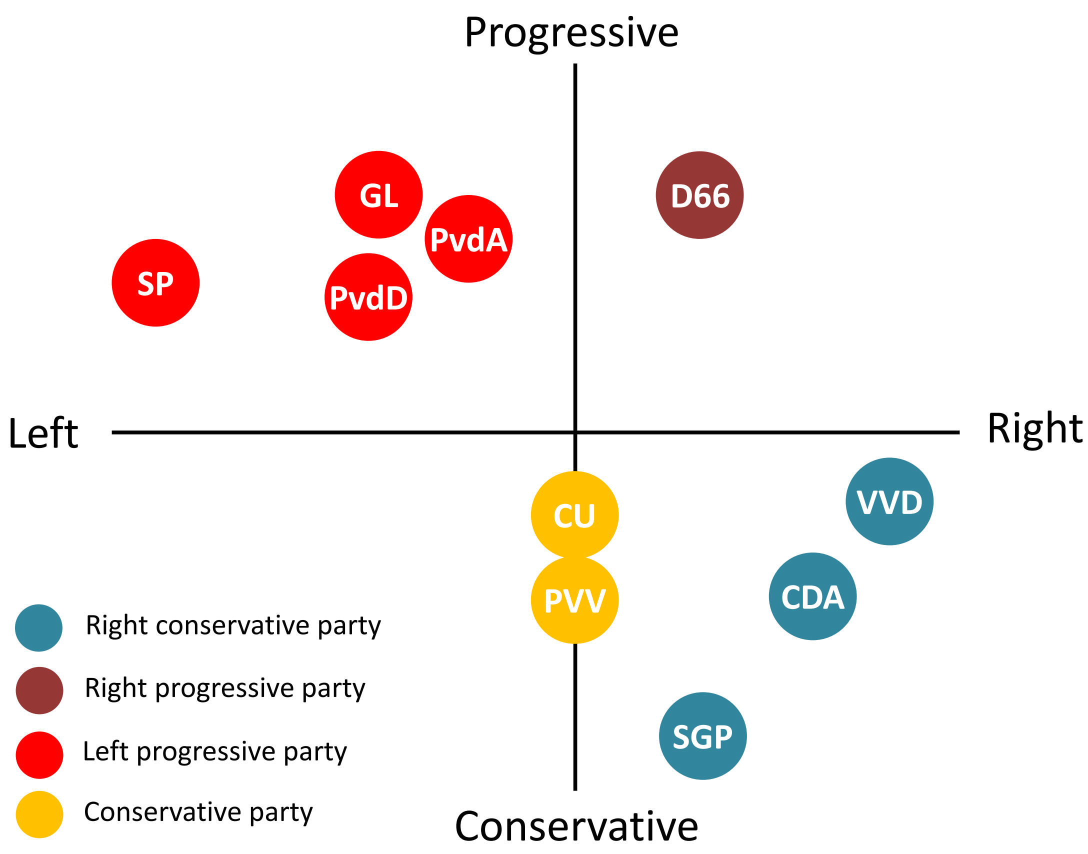


Figure 4-1 Positions of Dutch political parties based on election programmes 2010 and 2012. Figure adopted from (Wall et al., 2012) and Kieskompas.nl (2014). For an overview of the abbreviations of the Dutch political parties see Annex 4.A.

4.3.2. Coding the Parliamentary debates

The Cabinet's CCS policies provide valuable insight into the vision of the majority of Parliament. However, as the Cabinet is composed by multiple parties its position cannot necessarily be assigned to one party in particular. A deliberation in Parliament is generally started through the submission of government memorandums, which are public and well documented. The first round of a deliberation between Cabinet and Parliament entails written correspondence, as Members of Parliament ask written questions to the Cabinet, which are answered on paper as well. The questions cannot always be attributed to a specific party as the questions are summarised in one document, which hampers detailed analysis. Another issue that complicates the use of these written questions for our analysis is that their main purpose is to clarify issues instead of giving own opinions. As such, these documents rarely contain clear and explicit argumentations. The written communication is followed by oral debates between Members of Parliament and the Cabinet. These conversations are recorded and the minutes contain almost word-by-word transcripts of each representative of a specific political party. We therefore used the oral deliberations for our analysis, and excluded all written questions and answers.

The analysis focuses on the views of Members of Parliament representing a political party. The views of the Cabinet have been excluded, as their deliberations only serve to support their proposed policies. We have focused on political parties that are currently represented in Parliament. Consequently, parties that were only present in the Parliament for one election period were excluded, including three parties, which focus on the interest of the senior Dutch population (Unie 50+, AOV, 50plus), as well as the abolished party of the LPF, as they did not or rarely issue a statement on CCS.

All parliamentary documents are available on the web (www.overheid.nl). We searched the database for the keywords 'CO_2 storage (in Dutch: 'opslag'), 'CCS', 'clean fossil' (in Dutch: 'schoon fossiel') and 'CO_2 capture (In Dutch: 'CO_2 afvang') that were issued from January 1st 1995 until April 1st 2014. Additionally, the documents needed to adhere to the following criteria:

- Search terms that appear in the entire document (not just in the title)
- Parliamentary documents from the Second Chamber (in Dutch 'Handelingen' and 'Kamerstukken') that report oral debates.
- The oral debate contained explicit arguments on CCS (either in favour or against).

The minutes of oral debates between Parliament and Cabinet were coded with NVivo10 (2012). Each statement received a code for its topic, whether it was in favour or against CCS, the party to which the speaker belonged, the policy that was proposed (if any) and the type of CCS technology that was discussed (if any in particular). The coding proceeded on a paragraph-by-paragraph basis. Any repetition of a statement within the speech of the Member of Parliament was ignored. However, when the speaker was interrupted, both interruption and response were coded, even when the same statement was used, as this indicates an increase in the relevance of argumentation given the constraints on time and use of interruptions in these debates that are allowed by the chair. The codes were clustered based on a previous classification of CCS statements (see chapter 2, Argument map) as defined in van Egmond and Hekkert (2012). Categories were added when the arguments used did not fit any of these pre-defined categories.

4.3.3. Assessing positions on CCS and climate ambitions of the political parties

It is difficult to measure the opinion on CCS directly, as most remarks in Parliament are indirect. As such, opinions have to be distilled from the different statements used in favour or against CCS. The ratio of the issued pro and con statements reflects the opinions of the parties. We furthermore extended our analysis by assessing the election programmes of the political parties, which were used to substantiate the parties' position on CCS. Five national elections were held in the period between1995 and 2014. As the election in 2003 was shortly after the one in 2002, many parties reused their programme of 2002.

For linking the argumentation and the opinions of the parties regarding CCS with their ideologies, we used the classification of the Dutch Voter Advice Application (Kieskompas.nl, 2014). The climate ambitions of each party were taken from the assessments of the independent Netherlands Bureau for Economic Policy Analysis (CPB, 2010 and 2012). This bureau calculated for each party the financial and social-economic consequences including CO_2 emissions based on the proposed policy in the election programmes. Subsequently, we made a relative ranking of the climate ambition of the political parties. Hereto, we defined the number of the highest CO_2 reductions as an ambition of 100%, whereas the highest increase of CO_2 was set as a climate ambition of 0%.

4.4. The parliamentary discussion

Between 1995 and April 2014 Parliament held 138 meetings with the Cabinet in which CCS was discussed. During these meetings 556 statements were issued by Members of Parliament of which many arguments were the same, similar or overlapping. The number of statements per year varied greatly (Figure 4-2), indicating that the intensity of the debate varied over time.

Until 2005 there was little attention for CCS in Parliament, which increased after 2005 and peaked in 2009. The period between 2005 and 2009 was dominated by the debate on planned coal-fired power plants and the possibility to apply CCS at these plants. The political agenda regarding CCS in 2009 was focused on the Barendrecht storage project. Strong local opposition triggered the discussion in Parliament on the necessity of the Barendrecht project and CCS in general (van Egmond and Hekkert, 2015). As a result of the political debate the Barendrecht project was cancelled in 2010 and all onshore CO_2 storage was banned shortly afterwards. Subsequently, the debate in Parliament on CCS decreased significantly.

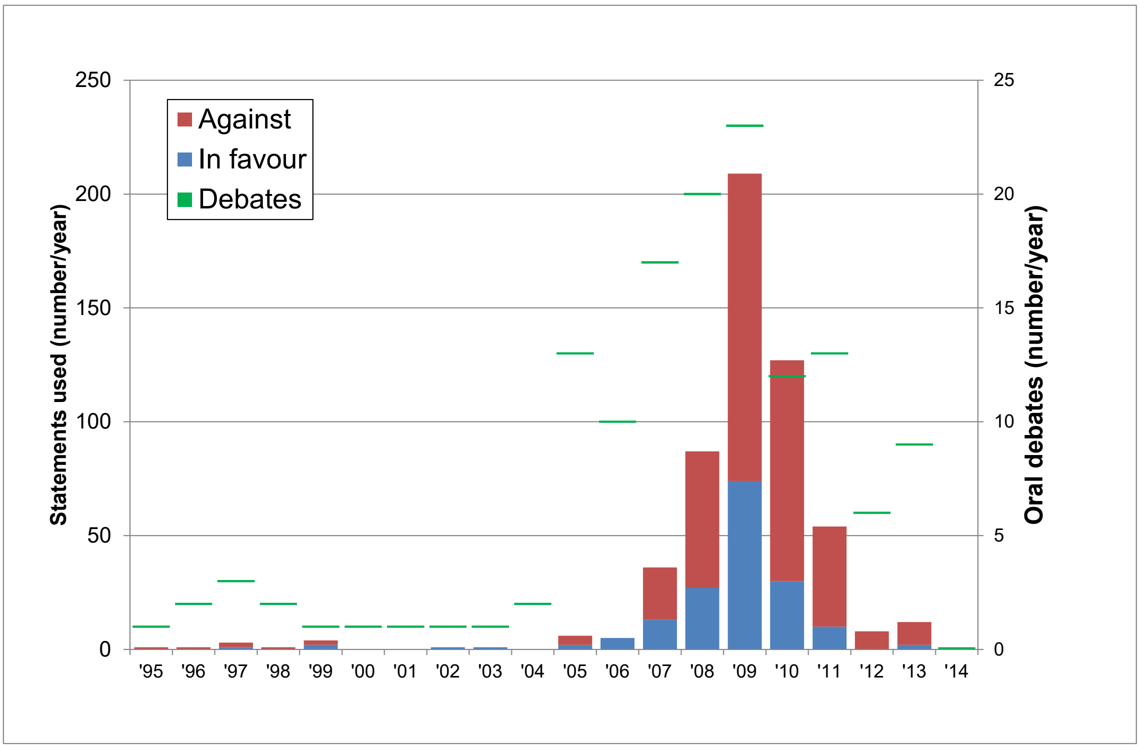


Figure 4-2 Development of number of oral statements on CCS used by Members of Parliament 1995- April 2014. Statements addressing arguments in favour or against are depicted in blue or red, respectively. The green dashes represent the number of oral debates on CCS.

4.4.1. Opinions on CCS technology in Parliament

We made an inventory of the opinions and arguments used in favour or against CCS. There was a large variety of opinions, ranging from complete rejection, conditional rejection, conditional acceptance, to acceptance of CCS. The main arguments in favour of CCS related to climate change (94 statements; see Table 4-1). The need for CCS to meet the climate targets in the Netherlands (59 statements) and CCS as a necessary transition technology towards a low carbon society (26 statements) were mentioned most often in this category. Economic arguments were mentioned as well. The good starting position of the Netherlands to implement CCS, due to its knowledge, infrastructure and availability of (nearly) depleted gas reservoirs was considered a positive economic argument (6 statements), which also applied to the opportunity to export CSS technology (7 statements). The statements in favour of CCS regarding safety were mainly replies to uncertainties on safety, and stated that CCS is safe and had been applied in the US for decades. Finally, we found several statements that called for political leadership to counteract local opposition on CCS (10 statements). The latter statements were not mentioned in the Argument map.

Category of argument	No. of statements	
	In favour	Against
Climate	**94**	**52**
Of which:		
CCS needed to meet climate targets	59	
CCS needed as transition technology	26	
CCS as an end of pipe solution		18
CCS is only a temporal solution		11
No climate policy needed		11
Economy	**22**	**31**
Of which:		
The Netherlands can export CCS	7	
The Netherlands has good starting position	6	
CCS is expensive		26
CCS has no other benefits		3
Energy	**15**	**153**
Of which:		
CCS is better than nuclear	13	
Prefer renewable energy		57
CCS costs a lot of extra energy		41
Safety	**16**	**27**
Political leadership[a]	**10**	
Not acceptable for public[b]	**0**	**58**
Uncertainty[a]		**61**
CCS technology is not ready yet		28
Other	**11**	**6**
Total	**168**	**388**

Table 4-1. The number of statements on arguments in favour or against CCS used by Members of Parliament in oral debates (1995-2014). The arguments are grouped in the categories adapted from Egmond and Hekkert (2012), see chapter 2 for the Argument map.
[a] not mentioned in Argument map.
[b] referred to as ethics in Argument map.

Whereas the arguments in favour mostly clustered on climate change, a multitude of different arguments against CCS were found. Many arguments were energy related (153 statements), as CCS would compete with implementation of renewable energy (57 statements).

Additionally, the energy cost for CO_2 capture was often mentioned as a drawback of CCS, as a significant amount of energy is consumed in order to get pure CO_2 from flue gases (41 statements). Climate arguments against CCS were also used (52 statements). For instance CCS was labelled as an end of pipe solution with no actual CO_2 reductions (18 statements) or the temporary character of CCS was highlighted (11 statements). Economic arguments concentrated on the cost of CCS (26 statements) and the lack of other benefits (3 statements). CCS was repeatedly referred to as an unproven technology (28 statements). Finally, the need for the Barendrecht storage project was often questioned, due to the lack of local support (58 statements).

4.4.2. Parliamentary opinions on CCS policy

In addition to arguments on the CCS technology itself, we found 147 statements on policy measures related to CCS. Supporters of CCS often pointed at the need for demonstration projects (33 statements) as well as the need for the development of knowledge and technology (25 statements). Several parties called for an obligation for CCS at coal-fired power plants (26 statements) or to make power plants capture ready (10 statements). Other parties argued that the industry should be able to determine their own low carbon technology, based on the European Trading Scheme (ETS) of CO_2 (16 statements). All parties rejected long-term public funding for CCS, but disagreed on short- and midterm public funding.

4.5. Climate ambitions and views on CCS of political parties

4.5.1. Climate ambitions of political parties.

As the aim of CCS is to reduce CO_2 emissions, we analysed the climate ambition of the various parties in Parliament. Table 4-2 shows that the green parties GL and PvdD had the highest ambitions for CO_2 emission reduction (100%). In sharp contrast, the PVV did not aspire to reduce CO_2 emissions at all (0%), but in fact accepted a small increase of CO_2 emission. The ambitions of all other parties varied between 63% and 15% reduction of CO_2 emissions.

Climate	Party	CO_2	Relative

ambition (ranking)		Reductions (Mt CO_2/year)	climate ambition (%)
High	GreenLeft (GL)	63	100%
	Party for the Animals (PvdD)	-	100%[a]
Above average	Labour Party (PvdA)	39	63%
	Christian Party (CU)	33	53%
	Progressive Liberals (D66)	31	50%
Below average	Reformed Christian Party (SGP)	22	36%
	Socialists (SP)	22	36%
	Christian-Democrats (CDA)	22	36%
Low/none	Conservative Liberals (VVD)	8	15%
	Freedom Party (PVV)	-1.5	0%

Table 4-2 CO_2 reduction ambitions for 2020 of Dutch political parties in election programmes. Percentages are based on the average of election programmes 2010 and 2012 (CPB, 2010 and 2012). The ambitions of GL and PvdD are set at 100%. The reduction ambitions were comparable between 2010 and 2012, except for the CDA, who decreased its ambition considerably in 2012. The CPB did not assess the election programmes of 2003 and 2006 on CO_2 emissions. In 2002 only a five parties were assessed. PvdA and CU showed a lower ambition than presented in this table, whereas the ambition of SP and D66 was higher (RIVM, 2002). In 2002 GL was the party with the highest climate ambition. [a] The election programme of the Party for the Animals (PvdD) was not assessed by the CPB on their own request. However, given their strong environmental agenda, we assume that the ambition for CO_2 reduction was comparable with the Green party (GL).

Figure 4-3 relates the climate ambition of the political parties to their ideological position, and shows that there is a trend for progressive parties to have higher climate ambitions, compared to conservative parties. The Christian parties (CDA, CU and SGP) have more climate ambition than the other two conservative parties (PVV, VVD), as shown in Table 4-2.

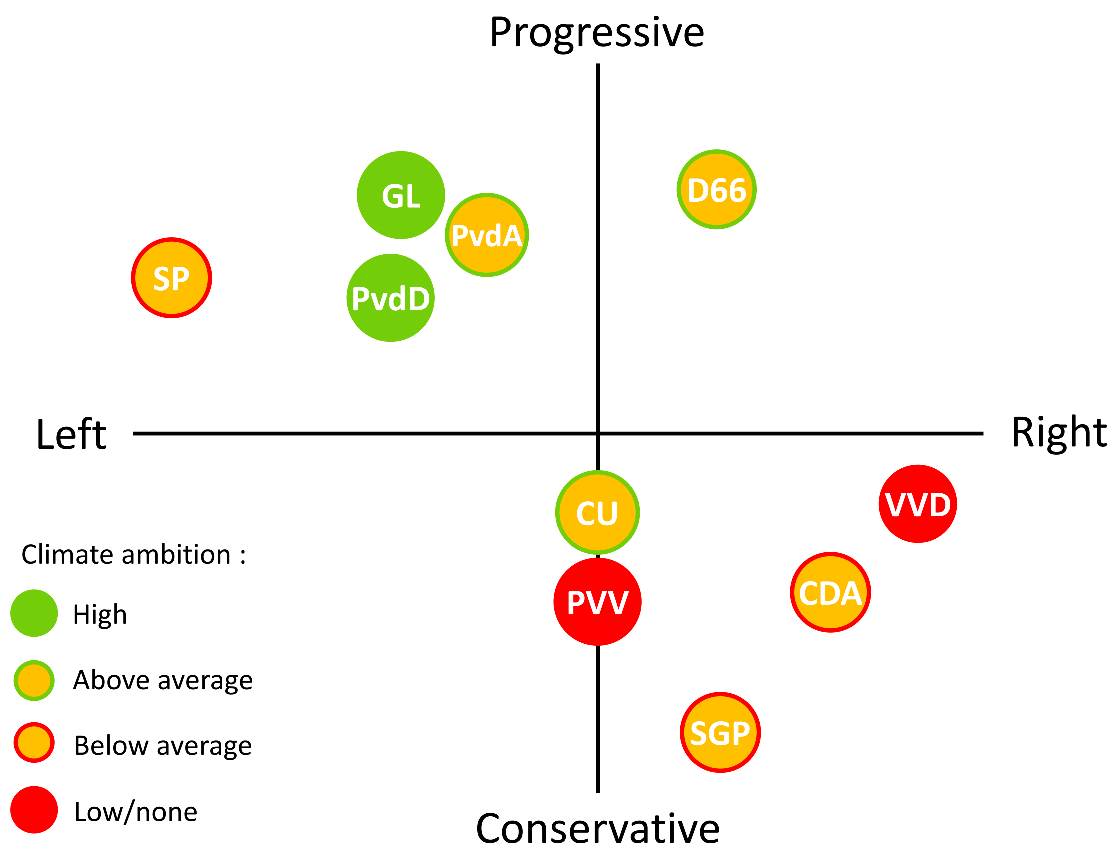


Figure 4-3 Climate ambition related to political ideology. The graph is extrapolated from data in Table 4-2 and Figure 4-1.

The position of political parties in the graph is based on a combination of multiple political issues. Based on this classification the CU and PVV are closely related. Climate protection is part of the conservative/progressive axis. The CU has higher climate ambitions compared to PVV, but their views on other issues in this scale like gay marriage and abortion etc. are more conservative. Conversely, PVV is more progressive on the latter issues, but has no climate ambition. On average, both parties therefore score similarly on this axis, in spite of their overt different views on many topics.

4.5.2. Views on CCS of the political parties

Similar to the ambitions to reduce CO_2 emissions, there was a large variety in opinions on CCS. In Table 4-3 political parties are clustered in three groups based on the percentage of statements in favour of CCS. The first group consists of D66, CDA and PvdA, which (conditionally) supported CCS. The second group, comprising CU, GL, VVD and SGP was critical, but did not reject CCS technology under all circumstances. The last group (PVV, SP and PvdD SP) opposed any form of CCS.

Position on CCS	Party	Percentage of pro statements	Number of statements	
			In favour	Against
Positive	D66	76%	59	19
	CDA	75%	33	11
	PvdA	72%	42	16
Moderate	CU	22%	8	28
	GL	21%	11	42
	VVD	14%	11	65
	SGP	10%	2	18
Negative	PVV	2%	1	58
	SP	1%	1	115
	PvdD	0%	0	16

Table 4-3 Position of political parties on CCS, and the number of expressed statements in favour or against CCS.

Assessing the number of statements in favour or against CCS in the debates provides a good indication of the overall opinion on CSS of the different parties, but does not offer information about the underlying motivations. Therefore, we analysed the content of the statements in the minutes of the debates of Parliament. In addition, the election programmes of the parties were examined.

Positive position on CCS

D66 supported CCS since the start of the debate and was one of the first parties to call for more financial support for CCS in their election programme (D66, 2002). This call aimed to store five megatonne of CO_2 in 2010, making D66 the only party that set a quantitative target for CCS (RIVM, 2002). D66 considered CCS a necessity to meet climate targets and foresaw economic benefits by exporting the technology. They advocated an obligation of CCS for coal-fired power plants as well as more public funds for the development of CCS (Parliament, 2005b and 2009a). They were the only party of the opposition that supported the Barendrecht project and called for political leadership to continue this project. In spite of their initial support, the D66 congress of 2010 accepted an amendment of the election programme, stating that CO_2 storage under residential areas was banned until more experience was gained from CO_2 offshore storage projects (D66, 2010).

The CDA aimed for the development of an affordable, reliable and sustainable energy system and argued for a broad energy mix, including fossil fuels and nuclear energy (CDA, 2010). The party supported CCS for a long time, which was envisioned as an opportunity for CO_2 emission reductions in their election programmes of 2006 and 2010 (CDA, 2006 and 2010). The CDA demanded that new coal-fired power plants must be capture-ready. Nonetheless, the decision whether CCS should be mandatory was left open. In 2009 the CDA was the first CCS supporter that started to refer to CCS as 'necessary evil' (Parliament, 2009g), and rejected the Barendrecht project in 2010. Climate ambitions were strongly reduced in the election programme of 2012, and CCS was not mentioned anymore (CPB, 2012; CDA 2012).

The PvdA preferred renewable energy and energy saving, but considered CCS as a necessary step in the transition to a fully sustainable energy system (Parliament, 2005a). Therefore, they conditionally supported CCS provided a strong policy for renewables was executed (Parliament, 2010b). They were in favour of the Barendrecht storage project until it was cancelled. In recent years they have framed CCS as a 'necessary evil' to meet the Dutch climate targets, but also stressed positive effects of CCS for Dutch economy (Parliament, 2008c and 2010b). They preferred an obligation for CCS for coal-fired power plants and were prepared to provide initial financial support to implement this (Parliament, 2007b).

Moderate position on CCS

CU had mixed feelings on CCS. Its opinion ranged between conditional acceptance and rejection unless specific criteria were met. In 2002 CU considered CCS as a temporary climate mitigation option, which could be of limited use (CU, 2002). Later they pleaded for obligating CCS at new coal-fired power plants (CU, 2010). In 2012 they accepted CCS as a temporal solution to meet climate targets, under the conditions that no other alternatives were feasible (CU, 2012).

GL is one of the parties with the highest climate ambition and is a strong advocate of renewable energy. They reject coal-fired power plants with or without CCS (Parliament, 2008d). When closure of coal-fired power plants proves impossible, GL aims for an obligation for CCS (Parliament, 2009a). Their opinion on CCS became more negative over the years. In 2006 it was referred to as an interesting option for the transition to a renewable energy system (Parliament, 2006). In 2009, it was stated that 'CCS would be accepted, but with the utmost repulsion' (Parliament, 2009g). GL had many doubts on short-term availability of CCS and was against the Barendrecht storage project as safety was not 100% guaranteed.

VVD has a preference for nuclear energy. It used CCS as a bargaining chip, as the VVD was willing to support CCS, provided the nuclear option would also be realised (Parliament, 2009g). Safety of CCS was not questioned (Parliament, 2009g). VVD was against any obligation for CCS and rejected public funding, as according to the party industry should be able to choose its own technological options. For a long time it was indecisive on the Barendrecht storage project before finally rejecting it, among others because it was afraid that this project would be the preamble of a CCS obligation (Parliament, 2010h). The VVD was the only party that never referred to CCS in its election programmes, suggesting a low interest in the topic.

SGP accepted CCS as long as it was affordable and implemented with care (SGP, 2010). It rejected the Barendrecht storage project, and did not express an opinion on policy measures linked to the stimulation of CCS.

Negative position on CCS

PVV considered 'CO_2 as a fertiliser for plants' and denied any link between CO_2 and climate change. Hence, the party rejected all kinds of climate policy, and thus on principle rejects CCS (Parliament, 2009g). According to the PVV CCS has no benefits, would only cost money and create risks. The party made a minor positive remark once on the possibility to use CO_2 injection for enhanced gas recovery (Parliament, 2011).

SP opposes CCS and argued against spending any public funding on CCS (e.g Parliament, 2009g). The delegation in Parliament mentioned the extra energy costs as the conclusive argument against CCS (e.g Parliament, 2009g). Consequently, the SP rejected the Barendrecht storage project. The party mentioned explicitly that it considered CCS technology to be safe (Parliament, 2009g).

PvdD rejected any form of CCS, as it is an end of pipe technology (PvdD, 2010). They also expressed concerns on the environmental impact of CCS.

4.6. Party policy, climate ambition and CCS opinion

Supporters of CCS mentioned the climate argument most frequently and framed the technology as indispensable for significant CO_2 reductions. In their argumentation the benefit of CCS was almost completely related to climate change mitigation. Therefore, we hypothesised a positive correlation between the climate ambition of a party and their support for CCS. In Figure 4-4 we show their positions on CCS related to the climate ambition of each party.

We do not observe an obvious correlation between climate ambition and CCS. This is mostly due to the fact that the parties with the highest climate ambitions did not overly support CCS or even rejected it. The PVV had no climate ambition and indeed rejected CCS. Contrary, GL and PvdD had the highest CO_2 reduction targets, but at the same time were (quite) negative about CCS. The parties with moderate climate ambitions like D66, PvdA and CDA took the most positive position. Thus, apparently there is no direct relation between climate ambition and the opinion on CCS. We therefore also considered the underlying argumentations of parties, upon which they based their opinion.

The PVV rejected CCS, based on the premise that human interference does not change the climate. Hence, the party disagreed with any climate policy, including CCS. On the other end of the spectrum GL and PvdD strongly agreed with the goal of CO_2 emission reductions, but they discarded CCS as a method to achieve this goal. In the ideal energy system of these parties, energy is produced locally in a renewable manner, as this would also results in a power shift from multinationals towards local energy initiatives. To GL the climate problem is a symptom of the current economic system and the party advocates a change of the whole system. Markusson and colleagues (2012b) described a similar combination of high climate ambitions and aversion to CCS by environmental organisations. Thus, the position on CCS can be seen as a composition of both climate ambition and acceptance of CCS as a method to reach the goal of CO_2 emissions reduction.

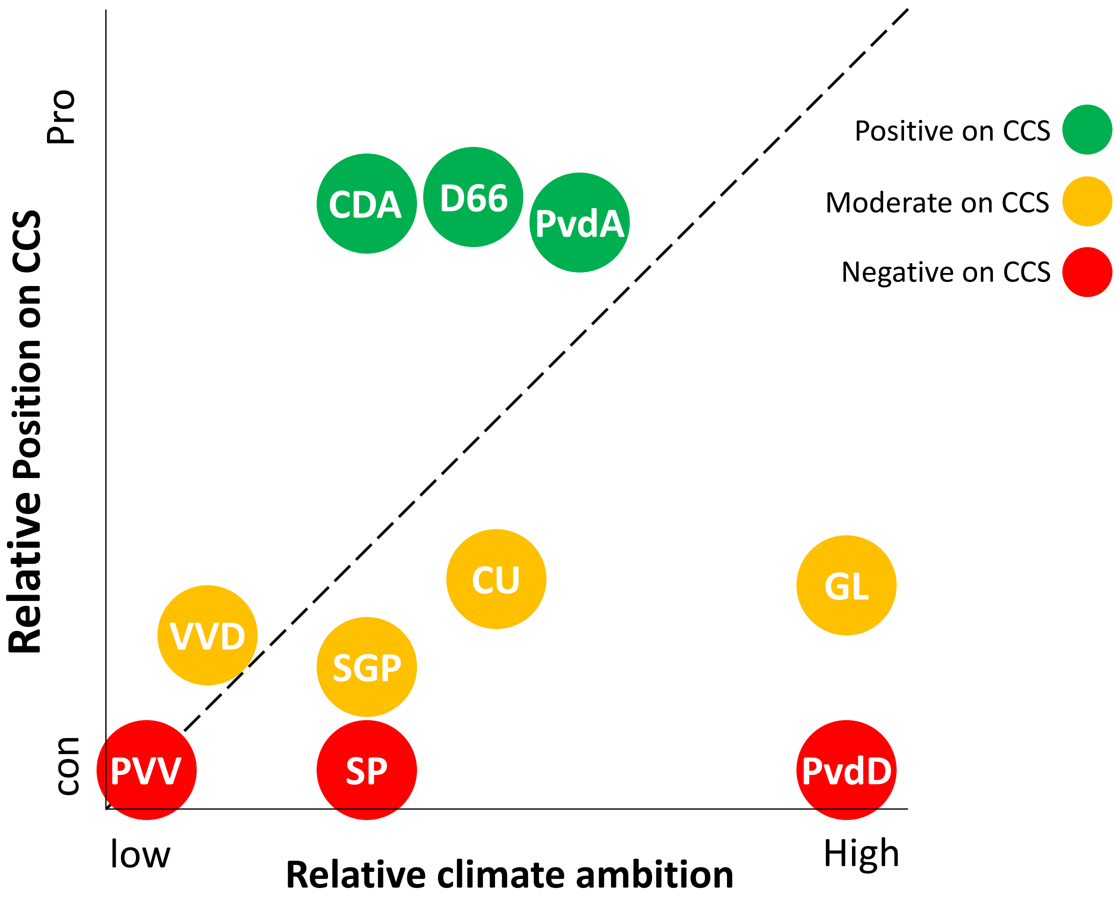


Figure 4-4 Opinion of political parties on CCS (indicated as relative position) versus climate ambition. The graph is based on data in Table 4-2 and Table 4-3. The hypothesised correlation is depicted as dotted line. The actual position on CCS and climate are shown for the different political parties.

In Figure 4-5 a new conceptual model is proposed in which the goal to reduce greenhouse gases and CCS as a climate mitigation method are separated.
In this model we defined 2 axes. One depicts the climate ambition of the political parties, whereas the other refers to acceptance of CCS as a method for climate mitigation. This yields 4 quadrants. In the two right quadrants the supporters of the CCS method are placed, whereas the CCS method is rejected by the parties in the two left quadrants. The upper or lower quadrants indicate a higher or lower climate ambition, respectively. We defined parties that are motivated to implement climate change mitigation options and consider CCS a good method to achieve their ambition as Unconditional Supporters. As they support both the goal and the method, they will include CCS in the political agenda. The upper left quadrant is composed of parties for which the climate change policy is an important issue on the agenda, but renewables are strongly preferred over CCS as method. Nonetheless, when CCS can be

implemented without risking slowing down the introduction of renewable energy, parties in this cluster will support certain policy measures. For example, an obligation for CCS at coal-fired power plants would be supported, as this will increase the price of traditional fossil electricity, thereby providing a competitive advantage for renewable energy, while simultaneously reducing CO_2 emissions. This group is referred to as Conditional Opponents, which reflects the aversion for the method of CCS, while its goal is supported. Unconditional Opponents are depicted in the lower left quadrant and parties in this group neither acknowledge the need for strong climate policy, nor do they accept CCS as technology. Finally, the lower right quadrant is composed of the Conditional Supporters, which are parties that are supportive of CCS as a method, but have relatively low climate ambitions.

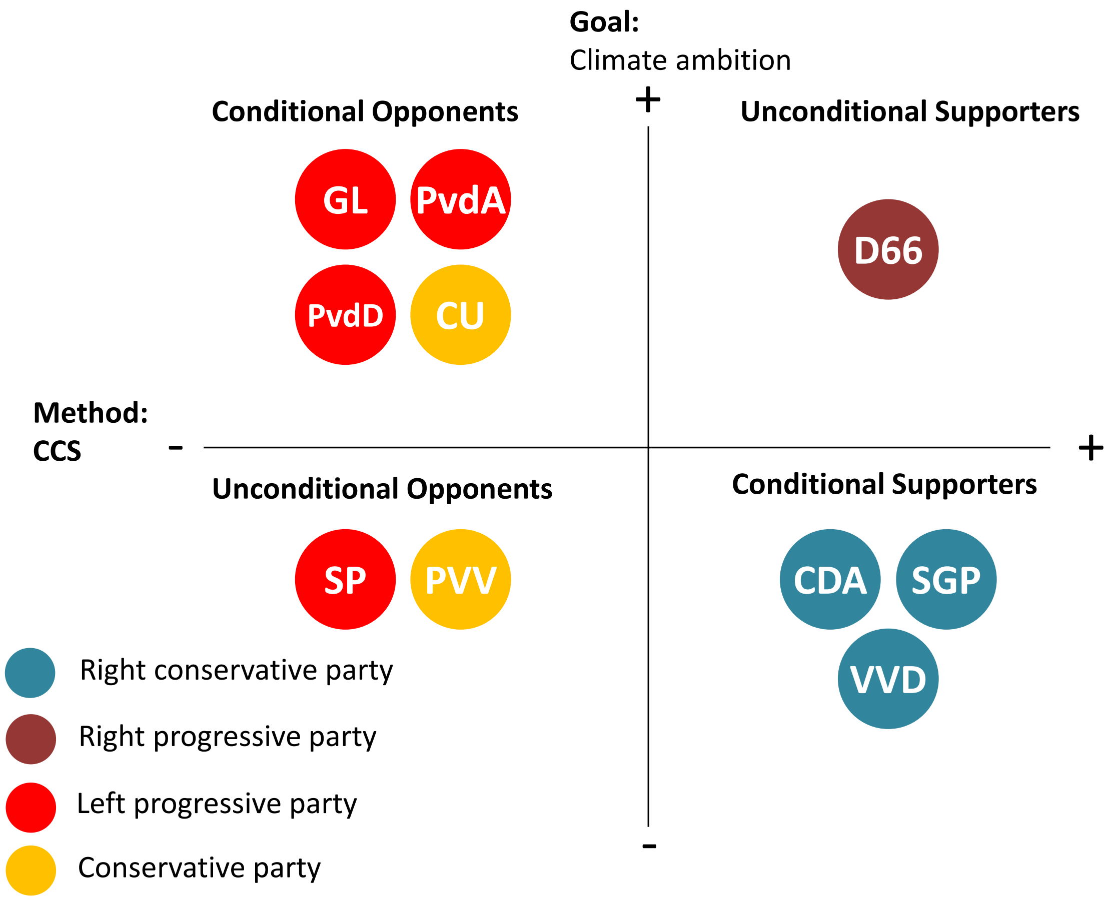


Figure 4-5 Conceptual model on the acceptance of CCS based on climate ambition and the method to reach climate goals. The method of CCS as a climate mitigation option range from reject (-) to accept (+), the climate ambition ranges from high ambitions (+), to low or none ambitions (-). Political parties are clustered per quadrant based on the statements used during the debate. Remark: initially PvdA and CDA were Unconditional Supporters, but after 2010 their positions shifted towards Conditional Opponents and Conditional Supporters, respectively.

When political parties are placed in the quadrant according to their views, four separate clusters can be identified. The Unconditional Supporters are composed of one party only, namely D66. Before 2010 PvdA and CDA also fell within this cluster. When the governmental ambition on renewable energy was reduced, the PvdA withdrew its support on CCS (Parliament, 2010b) shifting their position to the upper left quadrant. As the CDA climate ambition decreased significantly, it shifted to the lower right quadrant (see note Table 4-2). GL and PvdD form the core of the Conditional Opponents, which also includes the CU, and since 2010 the PvdA. Unconditional Opponents includes the SP, which rejects CCS as it would cost extra energy to capture CO_2, which interferes with their view on energy saving. Presumably, the PVV falls within this category as well, as they are reluctant with regard to new energy technologies. Neither party has strong climate ambition, although the SP acknowledges the need for climate policy. For the Conditional Supporters VVD, SGP and CDA CCS is an acceptable technology. However, they do not feel the strong need to direct climate policy towards CCS. Moreover, they favour the market as driving force for CCS implementation.

Based on this analysis for the Netherlands we can conclude that progressive left wing parties are Conditional Opponents, whereas right conservative parties are Conditional Supporters. We postulate that CCS as a technology better fits with the viewpoint of right wing parties compared to left wing parties as it relates to large industrial installations and allows the current energy regime players to continue with their business models. The only right wing party with climate ambitions is D66, and accordingly falls within the category of Unconditional Supporter as it supports both the goal of CCS (prevention of climate change) and CCS as a method to realise this goal.

4.7. Conclusion and discussion

In this chapter we analysed the viewpoints and argumentations of the Dutch political parties in relation to CCS. The analysis clearly shows that there are no simple relations between the position concerning CCS and the climate ambitions of political parties, in contrast to our original hypothesis. Additionally, neither the right-left distinction nor the progressive-conservative axis show clear relationships with the parties' positions on CCS.

Based on these findings we can explain the problematic introduction of CCS in the Netherlands due to the lack of Unconditional Supporters (only one political party: D66). The majority of the Dutch political parties (see

Figure 4-4) are Conditional Supporters or Conditional opponents of CCS. The Conditional Opponents support climate policies, but prefer other climate mitigation technologies over CCS. The Conditional Supporters may support CCS as an abatement technology, but have relatively low ambitions with regard to climate policies. In this constellation, it is unlikely that there will be a majority of Unconditional Supporters in Parliament soon. The number of Unconditional Opponents that completely reject CCS is also limited and is a minority as well. The majority of Parliament is not overly enthusiastic, but does not completely reject CCS either. According to de Best-Waldhober et al. (2009) this also holds for the Dutch population.

If CCS should contribute towards climate mitigation, as proposed by several organisations (e.g. IEA, 2013a; WEC, 2013) more Unconditional Supporters are needed. We see two possible routes to enhance the support for CCS. In Figure 4-6 these routes are graphically shown. It is unlikely that Unconditional Opponents are easily convinced on the necessity of CCS, as they reject both the goal to reduce CO_2 emissions and CCS as a method to realise climate mitigation. However, Conditional Opponents and Conditional Supporters, which have more moderate views only have to change position on one factor, in order to become more supportive of CCS. This opens opportunities for the formation of advocacy coalitions (Sabatier, 1988) in favour of CSS, which we describe in the next two subsections.

From Conditional Opponents to Unconditional Supporters

A strategy to change Conditional Opponents in Unconditional Supporters is to apply CCS in such a way that it does not conflict with deep beliefs on how the energy system as a whole should change. Specifically, CCS should not harm the introduction of renewable energy. Currently the debate of CCS is strongly related to coal-fired power plants. When a particular application of CCS was mentioned, 90% of the statements were linked to coal-fired power plants. The use of coal is however negatively perceived in the Netherlands, especially by left progressive parties (Parliament, 2009f).

The other few times application of CCS was mentioned it was related to hydrogen or natural gas production and framed in a positive manner. We therefore recommend that CCS proponents broaden the debate by stressing that CCS should be applied in other industrial processes as well. Other applications of CCS are not only perceived more positive, but CCS at refineries, steel plants and ammonia production factories do not compete with wind and solar energy in the energy system. These types of industrial applications have little alternatives to become low carbon, making CCS much more interesting for Conditional Opponents that have high climate ambitions.

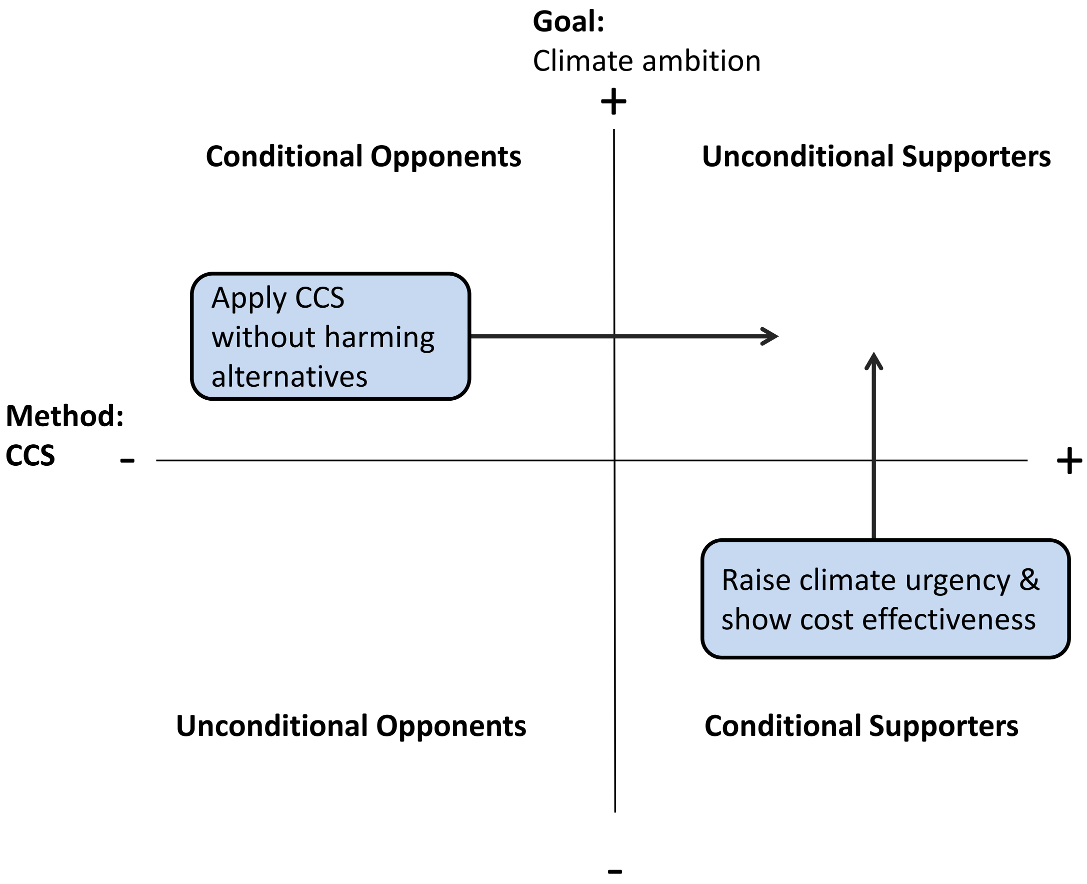


Figure 4-6 Possibilities to increase support of CCS by targeting the relevant arguments

The other few times application of CCS was mentioned it was related to hydrogen or natural gas production and framed in a positive manner. We therefore recommend that CCS proponents broaden the debate by stressing that CCS should be applied in other industrial processes as well. Other applications of CCS are not only perceived more positive, but CCS at refineries, steel plants and ammonia production factories do not compete with wind and solar energy in the energy system. These types of industrial applications have little alternatives to become low carbon, making CCS much more interesting for Conditional Opponents that have high climate ambitions.

From Conditional Supporters to Unconditional Supporters

For the Conditional Supporters CCS becomes an attractive option when they are forced to acknowledge the need for stronger CO_2 emission reduction targets. When international pressure increases to apply a more stringent climate policy, the position of Conditional Supporters may quickly shift. Future energy scenario's show that meeting climate targets with CCS is much cheaper than when CCS is excluded, which is a key argument that may sway this group (ECN, 2007). This cost efficiency argument was never used in Parliament so far, but it would suit right conservative parties well. Another argument that fits with their agenda is that CCS could provide energy security under more stringent climate targets.

In conclusion, implementation of CCS in the Netherlands as of yet failed due to a lack of sufficient Unconditional Supporters, rather than due to strong opposition by Unconditional Opponents. In this chapter we linked positions on CCS to political ideology. Progressive left wing parties have in general high climate ambitions, but prefer renewable energy over CCS, and can be considered as Conditional Opponents. By contrast, right wing conservative parties consider CCS a suitable option, but have a lower priority for climate policy. These parties can be classified as Conditional Supporters. Based on our analysis we indicated how advocacy coalitions can be forged to increase support for CCS, and we described two routes that may lead to more unconditional political support for CCS in the future. To convince Conditional Opponents it is necessary to position CCS as an acceptable method without threatening their desired sustainable energy system. By contrast, Conditional Supporters will be more easily swayed by the argument of cost-effectiveness of CCS in case of more stringent climate policies.

4.A. Annex: Abbreviations and names of Dutch political parties

Dutch Abbr.	Translated full name	Seats in Parliament						
		1994	1998	2002	2003	2006	2010	2012
PvdA	Labour Party	25%	30%	15%	28%	22%	20%	25%
VVD	People's Party for Freedom and Democracy	23%	19%	29%	29%	27%	14%	9%
CDA	Christian Democratic Appeal	21%	25%	16%	19%	15%	21%	27%
D66	Democrats 66	16%	9%	5%	4%	2%	7%	8%
GL	GreenLeft	3%	7%	7%	5%	5%	7%	3%
SGP	Reformed Political Party	1%	2%	1%	1%	1%	1%	2%
CU[a]	Christian Union	3%	3%	3%	2%	4%	3%	3%
SP	Socialist Party	1%	3%	6%	6%	17%	10%	10%
PVV	Freedom Party					6%	16%[b]	10%
PvdD	Party for the Animals					1%	1%	1%
Other		7%		19%	5%			1%

Table 4-4 Abbreviations and names of most prominent Dutch political parties. Description and names adopted from Andeweg and Irwin (2009) and Woerdman (2013); seats (%) in Parliament calculated from Leiden University (2013). The percentages underlined indicate that the party was part of the Cabinet.

[a] Before the merger in 2002, two separated parties (RPF and GPV)
[b] The Freedom Party was formally not part of the Cabinet, but it had a special supportive status.

5. Interaction between science and societal debate on CCS[1]

5.1. Introduction

The societal debate on CCS shows that CCS is a contested technology. The scientific community on CCS plays an important role in providing the knowledge about this technology. For example, it is the scientific community that produces models on the behaviour of CO_2 in the subsurface, which is relevant for assessing the safety of CCS. Furthermore, it develops techno-economic models that are necessary to estimate the associated costs and benefits. Moreover, environmental questions related to CCS, like the emissions of chemical waste and toxic gases are evaluated. By developing new solvents as well as new generations of capture technologies, scientists aim to reduce the energy penalty of CCS, which represents one of the major disadvantages (Yang et al., 2008). Energy models are developed to assess the role of CCS in meeting climate targets. Scientists can provide the perspective and the knowledge behind the arguments, and by developing new technologies some drawbacks of CCS might be reduced. Finally, social science increases our knowledge of the policy and social and economic processes that stimulate or hamper CCS implementation.

In the introduction chapter (Chapter 1) we made an inventory of how the natural and social sciences can contribute to knowledge about a technology, which may help policy makers to define their viewpoint on CCS. We use that background in this chapter to describe and evaluate the main Dutch research programme on CCS (CATO), comprising over 90% of the scientific activity on this topic in the Netherlands. The goal of this chapter is to describe how scientific knowledge development in the CATO programme has influenced the development of CCS as a climate mitigation technology in the Netherlands. First, we describe the issues that have dominated CCS research in the Netherlands. Second, the quality and quantity of CCS research in the Netherlands is assessed. Finally, we evaluate how the scientific community interacted with the on-going societal debate and how CCS is evaluated by this community.

To analyse the scientific effort on CCS in the Netherlands we focus on the CATO programmes, which are the national Dutch CCS research

1 This chapter is adapted from S. van Egmond, J. H. Brouwer, G.J. Heimeriks and M.P. Hekkert, 2012. Overview and analysis of the Dutch CCS program as knowledge network, International Journal of Greenhouse Gas Control, 11, S1–S9.

programmes. CATO is the Dutch acronym for Carbon Capture, Transport and Storage (CO_2 Afvang, Transport en Opslag). The first CATO programme started in 2004. Later the Dutch government expressed its ambition to realise one or two large-scale demonstration CCS projects in the Netherlands by 2015 with the goal to become a CCS frontrunner in Europe (Economic Affairs, 2008). This was based on the proposal of the European Union in 2007 to implement several demonstration projects within 10-15 years (EC, 2007). To this end a 'National Taskforce CCS' was established in 2008 as a combined public and private initiative. At that time it was concluded that continuation of CATO would be essential to provide the necessary knowledge and technical support for the Dutch demonstration projects. The first CATO programme, currently referred to as CATO-1, lasted from 2004 until 2009, and was mostly focused on fundamental research. In 2009 the CATO-2 programme was established with a mission to facilitate the integrated development of CCS demonstration sites in the Netherlands, in line with the ambition of the government. Part of the research was therefore directly linked to questions that arose from the implementation of real CCS projects. CATO-2 aimed to supply knowledge for the full CCS chain, including capture, transport and storage as well as public perception and legislation. In addition to applied research, part of CATO-2 was dedicated to fundamental research. CATO-2 also continued to build a strong knowledge network for CCS. We use the generic term CATO when specific activities cannot be separated due to the longitudinal nature of the programme. In Table 5-1 an overview of the key characteristics of both programmes is shown.

The data for this chapter were derived from a detailed analysis of all CATO programme documents and 13 semi-structured interviews. We used the publicly available final reports (CATO, 2009 and 2014), but we also had access to all documents related to the six sub-programmes and 53 work packages. Furthermore, insight was gained from detailed financial data of the CATO programme. For measuring the scientific impact of CATO we used the Web of Science database. The latter is described in more detail in section 5.5.

	CATO-1	CATO-2
Number of partners	17 partners of which: – 7 Companies – 5 University's – 3 NGO's – 2 Research institutes	35 partners of which: – 19 Companies – 9 University's – 1 NGO[a] – 3 Research institutes – 2 (Semi-)Government – 1 Other[b]
Focus	Full CCS chain	Full CCS chain
Type of research	Fundamental research	Fundamental and applied research
Budget	25 Million Euro	60 Million Euro
Period	2004-2009	2009-2014

Table 5-1 Key characteristics of CATO-1 and CATO-2 (CATO, 2009 and 2014). [a] One other NGO left halfway of the programme and is not counted here. [b] A public-private partnership.

5.2. Background on the CCS research in the Netherlands

Power supply in the Netherlands is largely based on coal-fired and gas-fired power plants. This is largely due to its geographical location bordering the North Sea and the relative large domestic natural gas resources. In view of the number of newly built fossil-fired power plants it is expected that the use of fossil fuel will not change soon. For the Netherlands, CCS can therefore represent a valuable means in the transition to a sustainable society (ECN, 2007; Economic Affairs, 2013).

The Netherlands have a long tradition in CCS research. The first papers date back to the end of the 1980's (e.g. Hendriks and Blok, 1989). Since then, Dutch universities and research institutes have participated actively in both national and international research programmes on CCS. Plans to establish a national R&D programme on CCS started in 2000. After four years of preparation CATO-1 was launched in 2004. Its successor CATO-2 started in 2009 and lasted until the end of 2014 (Table 5-1).

It took four years to prepare for CATO-1, whereas the planning for CATO-2 was realised in one year, which can be seen as an indication of the political interest in CCS in the Netherlands. In 2000 CCS did not play a significant role on the Dutch political agenda. The '*Clean and efficient programme*' (Environmental Affairs, 2007), which included an announcement of the Dutch government to participate in the European demonstration programme, changed the political landscape and allowed for a swift launch of CATO-2. Moreover, whereas in 2004 only 17 partners participated in CATO-1, 35 parties joined CATO-2 in 2009 (Table 5-1).

The conditions to start CATO-2 were favourable. CATO-1 established a CCS network and developed the skills and knowledge base necessary to implement CCS in the Netherlands. In the meantime, also the interest from the Dutch government in CCS increased. As CCS became an important part of the new Dutch climate change policy, external reviewers of the programme regarded 'CATO-1 as a welcome gift to the government', since it had generated a solid knowledge foundation (Thambimuthu et al., 2007).

When CATO-2 materialised, major industrial parties in the Netherlands were already engaged (or preparing to engage) in a number of small-scale CCS pilot projects and two integrated large-scale demonstration projects. CATO-2 was therefore timely, as demand from industry was clear and present. This is also reflected in the attendance records of Dutch conferences on CCS (see Figure 5-1). The first conference was held in November 2005 with almost 200 participants. Attendance increased to 440 in 2008 when the conference coincided with the opening of the CATO CO_2 catcher at the E.ON coal-fired power plant on the Maasvlakte in the Rotterdam harbour area. After 2008, the number of participants gradually declined, which was likely due to the delay and cancellation of several CCS pilot and demonstration projects in the Netherlands. In 2014 the number of participants increased again, partly due to the attendance of (62) international participants.

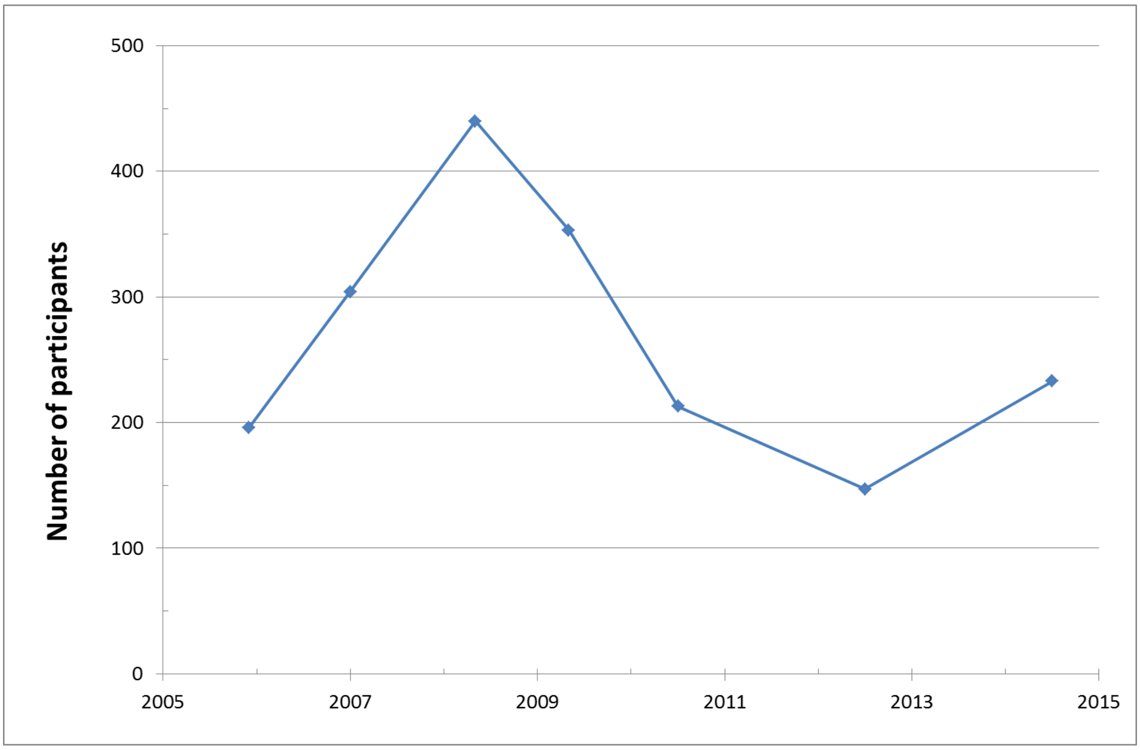


Figure 5-1 Number of participants for the bi-annual Dutch CCS conference. Data was obtained from the CATO programme office.

5.3. The structure and content of the CATO-2 programme

CATO covered entire CCS chains. Besides technology issues related to capture, transport and storage, also social scientific research was performed addressing legislation, risks and public perception. The CATO-1 programme focused on fundamental research, whereas CATO-2 addressed the complete innovation trajectory from fundamental (Discovery) to Development and implementation (Deployment) activities (EC, 2006). As CATO-2 applied a more integrated approach and was the most recent programme, this section mainly focuses on CATO-2. Major objectives of CATO-2 were to integrate activities in relation to research themes (Figure 5-2, vertical axis) and technology readiness levels (Figure 5-2, horizontal axis; Discover, Develop, Deploy). The number of activities decreases when technology matures indicating a funnel-type of setup, where successful trajectories are retained and unsuccessful trajectories are ended. For example, several fundamental research projects on new capture technologies were included in the programme, but in the application only a few technologies were deployed. When the technology was in the deployment phase the activities were linked to a concrete project on a location. The red lines illustrate knowledge accumulation going through the different technology development phases.

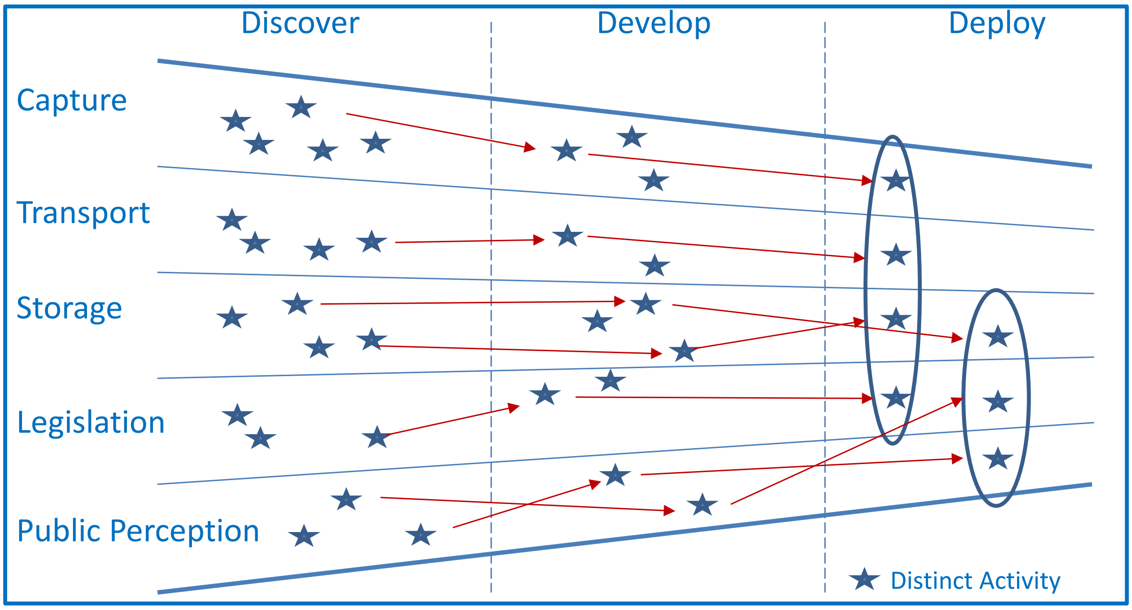


Figure 5-2 Schematic model of the activities in the CATO-2 programme. Stars indicate a distinct activity. The ovals indicate the implementation of actual CCS projects at specific locations.

The programme was designed to facilitate knowledge integration, i.e. to enhance interactions between the research themes. It was based around a matrix of research themes, referred to as Sub-Programmes (SP) and the locations for implementation of actual projects (See Table 5-2). The CCS sites where capture, storage and integrated technology were deployed are shown as Location 1, 2, 3, and 4. Additionally, columns have been added to the matrix for fundamental as well as general applied research. The latter refers to applied research, which was not directly linked to a specific location, for example on CO_2 transport. Most of the fundamental work was not directly related to specific locations either, whereas some of the more general applied work related to multiple locations. SPs consisted of several work packages (WPs). A group of stakeholders from industry/SME, NGO or Semi-Government was assigned to each WP.

Sub-Programs	Fundamental	General Applied	Location Specific			
			L1	L2	L3	L4
Capture	**x**	**x**	**x**		**x**	
Transport	**x**	**x**		**x**	**x**	**x**
Storage	**x**	**x**	**x**	**x**		
Legislation	**x**	**x**	**x**			**x**
Public perception	**x**	**x**	**x**		**x**	

Table 5-2 Impression of the organisation structure of the CATO-2 programme.

Thirty-five partners and approximately 400 persons participated in the CATO-2 programme. Partners can be divided into 5 clusters: Academia, Research Institutes, Companies (including large scale industry and Small and Medium-sized Enterprises; SME, which consisted of consultancy), NGO, and (semi)-Government.

The total budget of CATO-2 was 60 M€, with equal private and public contributions. Almost half of the research budget was allocated to research institutes, see Table 5-3. The remainder was mostly distributed to universities (18 M€) and companies (13 M€), whereas the other partners had a lower budget. All parties were invited to participate in an iterative earmarking process, which allowed the assignment of budget to the WPs as defined in the programme matrix. This process was done to ensure a demand driven programme instead of a programme with mostly academic interests. For those WPs that showed sufficient stakeholder support (and hence attracted sufficient budget) a detailed WP description was drafted, taking into account input from those parties that explicitly earmarked these WPs. WPs that did not attract sufficient support were discarded and the assigned budget was re-allocated by the stakeholders.

Type of partner	Budget (M€)	Number of partners
Research institutes	28	3
Universities	18	9
Industry/SME	13	19
(Semi-)Government	0.6	2
NGO's	0.2	1
Other	0.1	1
Total	60	35

Table 5-3 Type of participants in CATO-2 and their research budget

Figure 5-3 depicts the participation of the partners in the various SPs in relation to the technology development phase. Whereas industry was involved in all SPs, Government and NGOs participated in a limited number of themes only, such as legislation and public perception.

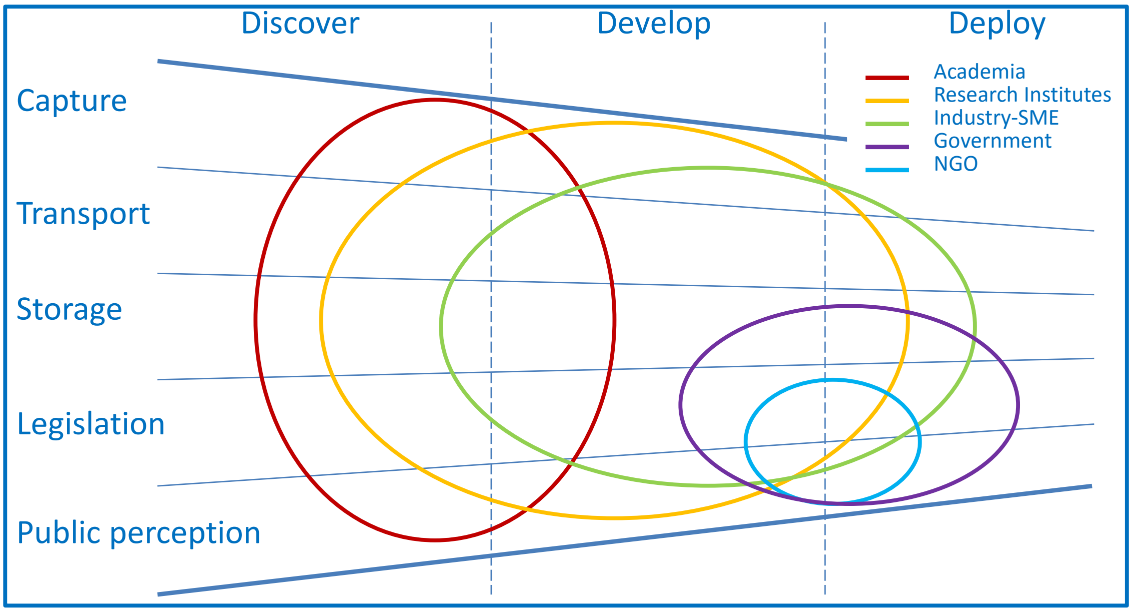


Figure 5-3 Schematic presentation of the involvement of the different partners in the CATO-2 programme.

The highest budgets of the programme were allocated to Capture and Storage (approximately 36% and 28%, respectively). The remaining budget was split between Transport and Chain integration, Legislation and Risks, and Public Perception (Table 5-4).

Sup programme	Budget (M€)
SP 0 Coordination and Dissemination	**7**
SP 1 Capture	**22**
SP 2 Transport and Chain Integration	**7**
SP 3 Storage and monitoring and verification	**17**
SP 4 Regulation and safety	**5**
SP 5 Public perception	**3**
Total	**60**

Table 5-4 Budget of Sub Programme in CATO-2

The latter (public perception) was an important factor in the programme, because of the societal impact of CCS as well as the occurrence of local opposition. Programme management and dissemination activities were both allocated 5% of the budget. With respect to Technology Readiness Levels the emphasis was on development (56%). Almost a third of the budget was allocated to fundamental activities (Discover). Deployment activities were to a large extent carried out by companies and received 13% of the budget.

The division of the budget can also be described on the basis of the type of research. Of the total budget of 60 million Euros 68% was allocated to natural science research, 12% to a combination of natural and social science research and 9% to social science. For other activities 11% of the total budget was allocated, including programme management and research on legislation.

When we look at the important topics that were addressed in the research, we arrive at the following division of the budget (See Table 5.5). Approximately half of the budget was allocated to activities with a major social impact, including safety (27%), public perception (5%), techno-economical analyses, including a roadmap (8%), environment (5%), and dissemination (5%) (Table 5-5).The other half was mainly distributed to technical aspects, such as cost reduction, scaling up technology, new generation of capture technologies.

Technological activities	Budget
Related to social impact	
Safety	27%
Techno-economical	8%
Environmental emissions	5%
Public perception	5%
Dissemination	5%
Technology development	43%
Other	8%
Total	100%

Table 5-5 Budget of technological activities and activities with major societal impact.

An overview of CATO-2 locations is provided in Table 5-6. It should be noted that most location activities have been discontinued. For example, the Barendrecht project where CO_2 storage was foreseen by Shell was cancelled by the national government. Later the national government banned all onshore storage, which resulted in the postponement of CCS at power plants in the Northern Netherlands (Eemshaven RWE and Eemshaven NUON). The projects K12-B, CO_2 Catcher Maasvlakte are still operational, whereas the CO_2 Catch-up Buggenum has been closed. The final investment decision for ROAD has not yet been made. Most large-scale demonstration projects were related to coal-fired power plants.

Location	Responsible Party	Description
CO_2 Catcher Maasvlakte	E.ON	capture pilot, post-combustion, small-scale, coal-fired power plant
Barendrecht	Shell	storage/transportation/legislation demo, depleted gas field, onshore, refinery
Delft Aardwarmte Project	TU Delft	injection/ production pilot, (geo-thermal) aquifer, onshore
North sea (K12-B)	Gaz de France	injection/ production pilot, producing gas field, offshore
North sea (Q8-A)	Wintershall	storage pilot, depleted gas field, offshore
Maasvlakte and North sea	ROAD (EON, GDF, TAQA)	integrated demo, post-combustion capture, storage in depleted gas field, offshore, coal-fired power plant
Eemshaven	RWE	integrated demo, post-combustion capture, storage in depleted gas field, onshore, coal-fired power plant
Eemshaven	NUON	integrated demo, pre-combustion capture, storage in depleted gas field, onshore
CO_2 Catch-up Buggenum	NUON	capture pilot, pre-combustion, small-scale, coal-fired power plant
Chemelot	DSM Agro	storage pilot/demo, aquifer, onshore, industrial source

Table 5-6 An overview of the locations that were included in CATO-2 programme. Demonstration projects are defined as large-scale integrated CCS projects. Depending on the technology a demonstration project has the size of over 0.4-0.8 Mt CO_2 per year (GCCSI, 2014b). Projects with a smaller size are referred to as pilot projects.

5.4. CATO as a knowledge integrating environment

Within CATO-2 the work is divided into 5 research SPs, which are further divided into 53 WPs. We analysed the participation of the 35 partners in CATO-2 WPs. We defined participation in a specific WP as executing paid activities. TNO participated in the highest number of WPs (38 out of 53), followed by ECN (19), Delft University (13) and Shell (12). On average 6 closely collaborating partners participated in each WP. The collaborative network is graphically presented in Figure 5-4. The figure shows the central position of TNO in the programme. The knowledge institute ECN played an important role as well. The focus areas of ECN were capture and system integration, whereas TNO covered almost all topics. Furthermore, Shell was an important partner, since it participated in all SPs.

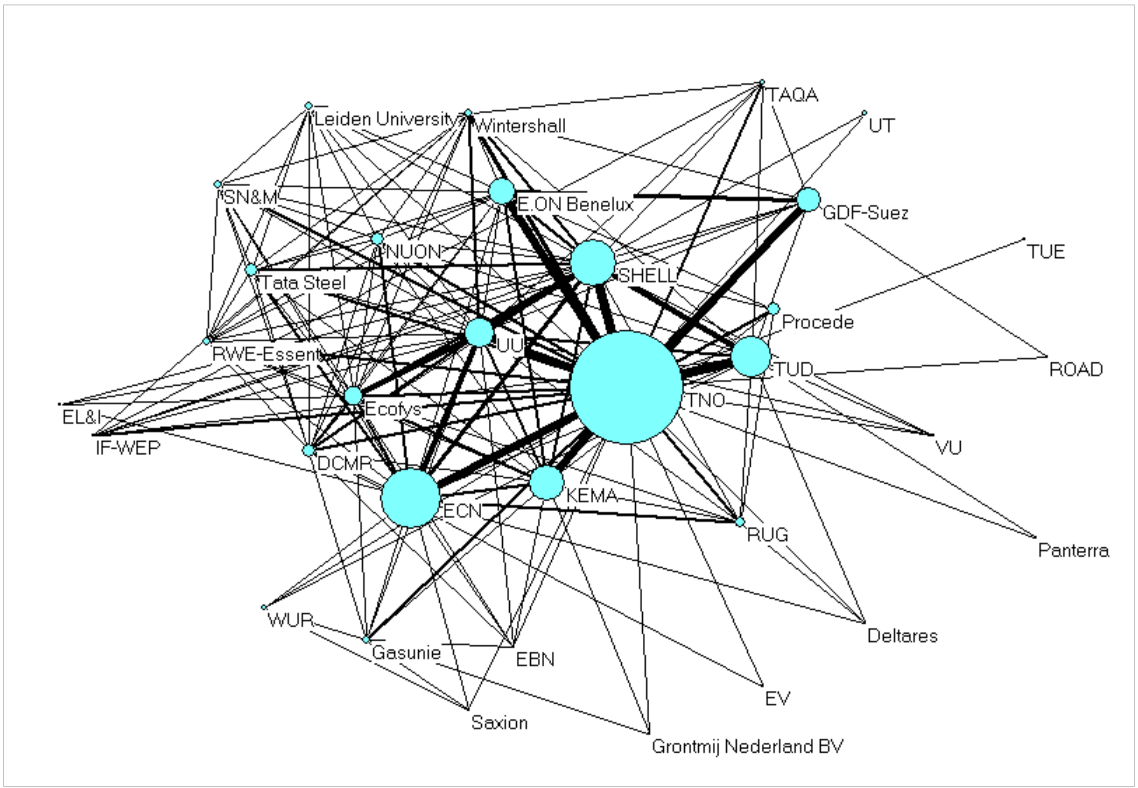


Figure 5-4 Network visualisation of WP participation in CATO-2. The size of the circles reflects the number of WPs in which the institute participated. The thickness of the line reflects the number of joint participants in the WPs.

Beside the formal organisation structure that supported interactions within CATO-2, the programme management paid a lot of attention to more informal activities, which contributed to a better integration of the programme. For instance, during the annual CATO symposium the research of the different partners was presented to the CATO community. The participation in the symposium is an indicator for the interest in the results and progress of the programme. During the CATO-1 phase, universities were the main participants. The share of the Research Institutes gradually increased and became the largest contributor to the symposium from 2008 onwards. The participation from industry increased after 2006, and declined after 2009, which can be explained as most of the CCS demonstration projects were cancelled or postponed at that time.

During CATO symposia and other meetings that were organised by the CATO programme office, sessions on general CCS issues and integration between different disciplines were strongly encouraged, in addition to exchange of in-depth knowledge among kindred spirits. For instance, on the one hand geologists were invited to participate in discussions on public perception and on the other hand non-geologists were stimulated to enhance their knowledge on storage issues.

Concluding, within CATO-2 the emphasis was on integration of Discover, Develop and Deploy activities as well as on collaboration between the research themes. Furthermore, informal types of activities helped to gain a better understanding of each other's scientific field. Nonetheless, pilot and/or demo projects are essential for true integration. For instance, the full impact of CO_2 impurities and flexible volumes of captured CO_2 only became evident when capture, transport, and storage were jointly addressed by academia, knowledge institutes and industry in the research related to the ROAD project. The postponement of multiple projects resulted in a decline of interest by especially the industry, which has hampered knowledge integration between the different activities.

5.5. Scientific impact of CATO

In this section we analyse the scientific output of CATO. The research performed in CATO was reported in deliverables, like reports, PhD theses, conference papers, and computer models. Overviews of the results of CATO-1 and 2 are provided in the public final reports (CATO (2009 and 2014). We analysed two indicators that reflect scientific output. First, the contribution of CATO to international literature was examined. As a second indicator we use the participation of CATO partners in other (international) research projects.

5.5.1. Contribution to international literature

There is a wealth of data available on knowledge generation as archived by the Web of Science from Thomson Scientific in the form of the Science Citation Index (www.webofknowledge.com). In our literature search we used the keywords 'Carbon AND Capture AND Storage' for the timeframe 1990 (when these keywords first appeared) till November 2011. Please note that this query represents the core of the CCS field, but does not address the entire field. However, using other keywords would introduce more ambiguity in the dataset, making interpretation more difficult. By taking a smaller sample, it is still possible to compare the Dutch contribution with the rest of the scientific world. All data found from the Web of Science contain institutional addresses, keywords, cited references and Journal names. The database thus enabled us to specify the number of publications, the locations, cited references and their topics (as indicated by keywords) of all research organisations.

We retrieved 1451 publications from the Web of Science. Publications on CCS appeared from the early 1990's onwards, but the number rapidly increased in recent years. The majority of papers were published after 2009. As can be seen in Table 5-7 the US contributed over 50% to the CCS knowledge base. There were 105 publications with at least one author located in the Netherlands. Based on this selection the Netherlands ranked seventh. The Netherlands contributed approximately 7% to the global scientific output on CCS, which is three times higher than Dutch contributions to other scientific fields (UNESCO, 2010).

Within the Netherlands, Utrecht University and ECN were the main contributors as their researchers published 29 and 18 manuscripts, respectively. Moreover, Utrecht University was the sixth institute worldwide publishing on CCS, after 4 American and one British institute. Universities and knowledge institutes published most, both in the Netherlands and globally. Shell was the only industrial partner that contributed to Dutch scientific publications.

Rank	**Country**	**number of publications**	**%**
1	US	791	54.5
2	England	232	16.0
3	Germany	135	9.3
4	France	131	9.0
5	Peoples R China	128	8.8
6	Australia	123	8.5
7	Netherlands	105	7.2
8	Canada	101	7.0
9	Norway	84	5.8
10	Sweden	76	5.2

Table 5-7 Top 10 countries of publications on CCS. Note that the total number of publications in this table is more than 1451, due to the fact that papers can have authors from multiple countries.

Out of the 105 Dutch publications, 19 were published by institutes that did not directly participate in CATO. Seven of these publications were generated by the European Union's Joint Research Centre in Petten, the Netherlands. Being an EU centre, it does not (directly) contribute to the Dutch knowledge base. Five publications were made by Dutch governmental bodies, which were not official partners of CATO, although they participated informally. Seven manuscripts were published by Dutch institutes that did not participate in CATO.

Concluding, based on the publication record, the Netherlands is one of the forerunners of knowledge generation on CCS. Since almost all Dutch publications were produced by partners of CATO, it can be concluded that CATO is the core of the CCS knowledge base in the Netherlands.

5.5.2. CATO partners participating in EU programmes

Another indicator of research output is participation of the partners in international programmes. We used the EU Cordis database[1], which covers the research and development programmes sponsored by the EU, to make an inventory of CCS related programmes (Cordis, 2010). The data covered the so-called Fifth, Sixth and Seventh Framework Programmes (FP5, FP6 and FP7), which span the period 2000 to 2010. The programmes varied from very specific CCS research, like NANOGLOWA that focused on nanostructured membranes for CO_2 capture at power plants, to more general CO_2 reduction programmes where CCS was only one of the topics, e.g. ULCOS, which focused on Ultra-Low CO_2 Steelmaking.

We identified 48 EU programmes related to CCS. In 41 of these programmes one or more CATO partners participated, with an average of almost 3 per programme. In 10 cases the CATO partner was the coordinator. TNO participated most in EU programmes (24 times), followed by several industrial partners such as Vattenvall, E.ON, Shell and RWE. Whereas the scientific output of the universities in terms of publications was highest among CATO partners, their participation in EU programmes was low. Twente University had the largest share (included in 5 programmes).

Thus, the CATO partners are very well represented in EU research and development programmes, and CATO knowledge is effectively disseminated to other European knowledge institutes through cooperation in European research programmes.

1 Community Research and Development Information Service (CORDIS) is a database devoted to European research and development (R&D) activities and technology transfer.

5.6. Interaction of CATO with Dutch society

At the start of CATO-1 in 2004, the consortium mainly consisted of universities and knowledge institutes. The interest for CCS outside the academic world was limited. The communication activities were more or less restricted to the scientific community and aimed at network building within CATO. During the programme the interest of industrial partners, policy makers, media and local residents on CCS increased, due to the development of CCS demonstration projects, like the Shell Barendrecht project. This resulted in an increase of media coverage and debates in Parliament. As a consequence, the need arose for accessible and independent public information on the arguments in favour or against CCS, as a new technology cannot be implemented unless it acquires legitimacy in society. The national government was reluctant to communicate on CCS towards the general public, which resulted in a discussion within the consortium on the role of CATO. Most scientists within CATO were convinced that CCS is needed to mitigate climate change and can be applied in a safe and acceptable way. Nevertheless, they were reluctant to become a public advocate of CCS, as scientific papers are meant to be unbiased. Scientific publications are, however, generally inaccessible for Dutch society. Yet, it is essential for society to have access to proper knowledge in order to judge whether and how CCS can be implemented. Consequently, CATO became more proactive in public communication, by providing the necessary input for an informed debate on CCS.

The relationship between CATO and the Dutch media, NGOs, critical external experts, industry, local and general public as well as policy makers is described below.

Media

According to the CATO programme management an open relationship with society, including journalists, was crucial for acceptance of a new technology like CCS. In some cases, however, the media may not present the relevant information or, even worse, present wrong information. CATO-2 therefore created a team that actively followed the media and refuted misconceptions by providing the facts in a balanced way. An example of this approach is the case addressing a possible leakage of CO_2 at the Weyburn project in Canada in January 2011 (PTRC, 2011). CATO responded fast with balanced statements to journalists, which resulted in several informative and balanced articles in national newspapers like the NRC (2011). To build a more structural relationship with journalists, CATO invited science journalists of the main Dutch newspapers to participate in a geological excursion to the Eiffel in Germany where natural CO_2 release occurs. During this excursion scientists shared their insight in geology with the journalists, and CO_2 release from the subsurface was put into perspective. An important result of the trip was that relationship and trust between scientists and journalists increased. This was beneficial since CATO scientists had become very cautious to talk to journalists, after previous biased media coverage. Thus, due to the efforts of CATO the relationship between CATO participants and science journalists improved.

Environmental NGOs

From the start of the programme a lot of effort was devoted to involve organisations in CATO with different ideas on CCS. In CATO-1 environmental NGOs, like Greenpeace and WWF participated in the programme. One of the missions of CATO-1 was to investigate whether CCS can contribute towards a sustainable Dutch energy system. As such, balanced views against or in favour of CCS were initially present within the consortium. Several NGOs did not favour CCS, as they preferred renewable energy. In the end, most NGOs, such as Greenpeace and the North Sea Foundation decided to end their participation, because they feared negative publicity as CCS became linked to coal-fired power plants. As a consequence, the opinion on CCS in CATO became less varied. The balance in CATO shifted towards a more pro CCS attitude. This misbalance also occurred in the CCS community outside the Netherlands (de Coninck, 2010).

Critical external experts

As part of the dialogue CATO aimed to continue the debate with critical scientists, within and outside CATO. For example, a workshop (at Utrecht University, 15 may 2010) was organised on the safety of CO_2 transport at the Barendrecht project. In this workshop (critical) experts participated together with some concerned inhabitants. Even though the initial ideas of the participants on the Barendrecht project were very different, the workshop bridged some of the gaps, and induced some mutual understanding. A number of science journalists participated in this workshop as observers.

Industry

The industrial partners had a strong influence on the design of the research agenda of the programme, due to the earmarking process of the budget in CATO-2. This was in line with the strategy of the Dutch government, which promotes an important role of entrepreneurs in defining the direction of research (VVD-CDA, 2010). Consequently, a large part of CATO focused on deployment. Furthermore, the capture part of the programme was mostly related to coal-fired power plants, as these were operated by several industrial partners. The CATO programme was therefore highly relevant for the industrial partners, which is illustrated by the quote of Peter Radgen of E.ON: 'Without the successful work of the CATO programme, it is doubtful that a project like ROAD could have advanced so far. The ROAD project has developed to be the most likely CCS project in Europe to be built' (CATO, 2014)'. The industry was thus initially very interested, but interest decreased due to cancelation of several demonstration projects.

The general public and local residents

The initial CATO website on CCS was written in English and focused on the scientific community (www.CO_2-cato.org). The communication with the general public is more challenging, as scientific manuscripts are less accessible and difficult to interpret for a lay public. Moreover, the questions and concerns of the general public are usually very different from the scientific questions, and are not often addressed in scientific literature. Hence, CATO established a Dutch website with general information on CCS for the public in 2011 (www.CO_2-cato.nl). The website attracted approximately 500 visits per month. The CATO programme also carried out several studies regarding the knowledge and beliefs of the Dutch public (de Best-Waldhober et al., 2012a and 2012b). These studies provided a good insight in the public perception of CCS in the Netherlands. The approach in these studies was one of observation rather than interaction. In the CATO-2 programme plan a local dialogue process was foreseen, which was developed by Leiden University in CATO-1. Due to cancellation of the Barendrecht project and all other onshore storage projects in the Netherlands it was not possible to apply this dialogue process.

Policymakers

The government commissioned the CATO programme. The government did not participate directly in CATO, but followed its outcome. Furthermore, the government not only strongly influenced the research topics at the start, but its policy continuously impacted the research agenda. For instance, the ban on onshore storage effectively cancelled most research on onshore demonstration projects, hereby shifting focus towards offshore storage. This also included research on the impact of CCS on maritime life and offshore monitoring techniques. The Ministry of Economic Affairs often consulted scientists in the programme, for example on the implementation of the EU storage directive. CATO developed an implementation plan for CCS in the Netherlands, which helped the government with establishing long term strategies. CATO did not have a lobbying strategy aimed at policymakers for CCS implementation. Thus, after issuing the programme the government was not directly involved anymore, but indirectly influenced the programme through legislation.

5.7. Conclusion and discussion

In this chapter the CATO programme and its contributions to the Dutch knowledge network on CCS were described. The programme dealt with the complete CCS chain of different phases in technology development. We showed that the Dutch (scientific) knowledge base on CCS was mainly established by the participants of CATO and that Dutch scientists on CCS are among the frontrunners worldwide. The CATO programme consisted mainly of natural science research, with 68% of the budget. Combined natural and social science research received 12% of the budget, while 11% was attributed to social science topics. The CATO programme management aimed at bringing natural science researchers and social science researchers in close contact with each other. The cooperation between different areas of expertise was particularly clear in demonstration projects. Additionally, demonstration projects triggered the interest of stakeholders, including industry, policy makers, media and the public. The developments in these projects drove the direction of the natural and social sciences research. Therefore, we found that demonstration projects are essential for integrated technology development.

A special characteristic of the CATO-2 programme was that half of the budget (30 M€) came from private partners and that the attribution of the budget to research subjects (work packages) was based on an iterative budgeting process with all involved partners. This was done to ensure a close link between knowledge production and knowledge demand. This influence of several stakeholders on the direction of the research in CATO, especially the involvement of industry, resulted in a focus on coal-fired power plants. NGOs were originally part of CATO, and voiced important questions and concerns. However, as they felt unable to significantly alter the research agenda, and because CCS became linked to coal-fired electricity generation, most NGOs withdrew. Similarly, critical experts became less involved, which shifted CATO to a less well-balanced position on CCS.

The policy of the government furthermore impacted the direction of CATO and its research, due to the ban on on-shore storage. Local opposition to CCS demonstration and media coverage led to an increased awareness of the importance of the social sciences within the CATO programme. Although CATO provided useful knowledge for demonstration projects of industry, industrial interest decreased when several demonstration projects were cancelled (as a result of the ban on on-shore storage). The influence of CATO on the opinion of the general public was limited. It turned out that it was difficult to inform society with the knowledge that was available in CATO. The root of that problem was not the quality of the research, but the large gap between science and the lay public. Most of the research topics within the CATO program could not easily be related to the most important topics in the societal debate. Another reason was the reluctance of CATO scientists to become public CCS advocates. This weakened the potential impact that CATO might have had on society.

CATO delivered knowledge that helped developing long term CCS policy by the government. In addition, CATO created human capital, as it produced new experts in all CCS fields. Because the programme management put a lot of effort in promoting open relationships with the media and public, the understanding of CCS by the scientific journalists significantly improved.

Concluding, the CATO programme had a classic scientific setup; there was no intention to stimulate a 'constructive technology assessment' process within the CATO programme, as described in Chapter 1. Because the CATO programme included several demonstration projects, the research and knowledge could be well integrated around these projects. However, this also led to a focus on demonstration and implementation and may have reduced a more critical stance on CCS, which can explain why NGOs and critical experts withdrew from CATO. Nonetheless, CATO has tremendously increased the scientific knowledge and expertise on CCS in the Netherlands.

6. Case: Failure of the Barendrecht CO_2 storage project[1]

6.1. Introduction

The introduction of new energy technologies is important for reducing greenhouse gas emissions. CO_2 capture and storage (CCS) is considered an important option to reduce CO_2 emissions to mitigate climate change (e.g. EU, 2011; IEA, 2013b; IPCC, 2005). However, the actual implementation of CCS is slow, as many planned demonstration projects have not been realised (GCCSI, 2012). Like other energy technologies CCS faces resistance of the general public. In order to understand the dynamics of energy technology implementation, it is therefore interesting to analyse the causes for discontinuation of CCS projects. The Barendrecht CO_2 storage project in the Netherlands is an important example of one of these demonstration projects.

In the Barendrecht project it was proposed that CO_2, produced at a nearby refinery, would be stored in two small empty gas fields that are located under the city of Barendrecht, which is a small municipality in the Netherlands (approx. 44.000 inhabitants). The Dutch government was responsible for the storage permits and financially supported the project, which would be executed by Shell CO_2 Storage B.V. Over time, local opposition increased, and the concept of CCS as well as its implementation was heavily debated in the Dutch Parliament, which ultimately led to cancellation of the project. The aim of this Chapter is to understand the local and national dynamics, and the interactions between these two, which led to the cancellation of the CCS demonstration project at Barendrecht.

6.2. Theoretical background

Wüstenhagen et al. (2007) show that the introduction of a renewable energy technology depends on three different types of acceptance: market, local community and (national) social-political acceptance. Even though CCS is not a renewable energy technology, according to the classic definition, environmental technologies deal with similar issues.

---

[1] This chapter is adapted from: S. van Egmond and M.P. Hekkert, 2015: Analysis of a prominent carbon storage project failure – The role of the national government as initiator and decision maker in the Barendrecht case. International Journal of Greenhouse Gas Control, 34, p. 1-11.

Firstly, the current acceptance of CCS by the market is generally poor, since viable business models for CCS are lacking (IEA, 2013b). It was also anticipated that the business case for the Barendrecht project was negative. Nonetheless, Shell chose to invest in the project for research and development purposes (Kuijper, 2011).

Secondly, local community acceptance is a problem for many onshore CCS projects (Huijts et al., 2007; Shackley et al., 2009). Five social science papers related to the Barendrecht project have previously been published. These studies mainly focused on the local context. Terwel et al. (2012) determined the attitudes of the population of Barendrecht towards the storage project. They found that the residents were negative about the CCS project, as a vast majority of 86% found the project unacceptable. Most residents stated that the project was 'unsafe' and 'very likely' expected that the project would diminish real estate value. Moreover, most residents perceived the decision-making process as unfair and they expressed distrust towards Shell and the national government. All these elements were significant in explaining the attitude of the population. Brunsting et al. (2011a) argued that the lack of proper local participation and good communication attributed to the local opposition. Shell and the government addressed the project mainly from a techno-economic angle, whereas the local community viewed it from a social and local perspective. This led to a mismatch in communication, and resulted in distrust of the local community towards Shell and the national government. The authors also argued that local participation in the decision process was too late, and residents did not have any real influence, which amplified the distrust and the negative attitude towards the project. Ashworth et al. (2012) and Oltra et al. (2012) compared several onshore CCS projects, and proposed several critical success factors that are needed for project implementation. Ashworth et al. (2012) argued that the absence of a communication expert at the launch of the project as an integral member of the team strongly contributed to local unrest. Another causative factor was the discord between the local, regional and national governments, which decreased the public confidence. The lack of flexibility to adjust the plans in accordance with concerns that were expressed by the public further raised opposition. Finally, they stated that the project did not have a proper 'social fit'. This term is used by Hammond and Shackley (2010) to describe how a CCS project fits within the social and cultural history of a specific location. Oltra et al. (2012) also pointed at the poor social fit, and the unfair distribution of costs and benefits. The community felt they were mostly burdened by the project, whereas Shell would gain the benefits. Moreover, a perceived lack of transparency by Shell and the national government on costs, risk and benefits, as well as a generic lack of trust in companies, in casu Shell, played an important role to spark local opposition. Shell described the key elements of a comprehensive public acceptance strategy based on the experience with the Barendrecht project (Kuijper, 2011). Like the other studies, Kuijper mentions good risk communication, a proper local value proposition, a good social fit and a consensus on the need for CCS as vital factors for local acceptance.

Thirdly, with regard to socio-political acceptance, most large (infrastructural) projects decisions do not rest with the local community, because the national government plays a crucial role. In the Netherlands, the Minister of Economic Affairs, who represents the government, has the authority to grant storage permits for CO_2. Additionally, the Department of Economic Affairs is responsible for Energy policy, and as such can grant financial support for CCS projects. The Dutch Parliament has a monitoring role and can adjust, approve or reject new laws that are proposed by the Cabinet. The Barendrecht project was cancelled by the national government after heavy debates in Parliament. The lack of local support was used as the main motivation (Economic affairs, 2010a). However, the national government is not always responsive to local opposition, especially when national benefits are deemed to outweigh local concerns. This is for instance often the case with constructing airports, rail roads or highways. A good example is the realisation of the railroad track for the Betuwe cargo route. In spite of intense local protest from the neighbouring communities the railroad track was built. Interestingly, one of the local communities was Barendrecht, but in this case their protests were mostly ignored (Parliament, 2004). Furthermore, in the same period that the Barendrecht CO_2 storage was debated, the local community at Bergermeer was unable to prevent a large natural gas storage project, despite substantial local protest (Gasalarm, 2011). The same Department of Economic Affairs was responsible for the storage permits and both cases were discussed at the same meetings in Parliament several times (e.g. Parliament, 2009g). Hence, local opposition may influence the national decision process, but is not the only explanatory factor for the cancellation of projects.

In this study we analysed the national decision making processes related to the Barendrecht project, including the influence of the local opposition. A better understanding of why the government changed position during the debate, ultimately resulting in termination of a prominent CCS demonstration project, may help to understand how future large-scale energy projects can be realised.

The main added value of this chapter lies in the fact that local opposition is not studied in isolation, but in relation with the national social-political actors.

In the next section we describe the methodology, which is mainly based on interviews and a process method. In section 6.4 we give background information on the Barendrecht project. In section 6.5 we present our timeline of the events, followed by an analysis in section 6.6. We end with discussion and conclusions in section 6.7. In Annex 6.A. the background of the Dutch national political system is presented.

6.3. Methods

Discussions and (national) decisions of the project were analysed according to the 'Historical Event Analysis' process method (Ven et al., 1999; Poole et al., 2000). An event is defined as the smallest unit of change that can be identified, for example a meeting, a news article, or a discussion in Parliament. The process approach conceptualises development processes as sequences of events. A process approach explains outcomes from the order of events, critical incidents and contextual factors (Poole et al., 2000). The effects of events are not equal; some events have a major impact on the final outcome while other events only contribute marginally.

Events were categorised as either local or national. Local events were related to actors at the level of the Barendrecht municipality, which includes local population and politics. National events were related to the national government as well as the regional administration, scientists and (inter)national non-governmental organisations (NGOs), as these parties do not have direct local interests. Shell acted on both local and national levels. Shell Storage BV, as the executer of the project, was part of the local level, whereas events related to the Royal Dutch Shell plc were categorised at the national level. We made this distinction because the interests of either party were not necessarily identical, even though there was obviously a lot of interaction between the Barendrecht project team of Shell and Shell headquarters.

For the event analysis of the local level, several academic papers that already addressed this issue in detail were used (Ashworth et al., 2012; Brunsting et al., 2011a; Kuijper, 2011; Oltra et al., 2012; Terwel et al., 2012). The literature search also included the newspaper database Lexis

Nexis, which covers Dutch newspapers since 1990 (Lexis Nexis, 2014), and official documents such as the (interim) permit application (Shell, 2008a). We found relevant data for the period 2006-2010.

The deliberations on the Barendrecht project in the Dutch Parliament were also used for this analysis. The minutes of parliamentary debates are almost word-by-word transcripts of the oral debates between Members of Parliament and the national Cabinet. The written correspondence between Members of Parliament and the Cabinet is also publicly available. We searched all these documents for the keyword 'Barendrecht', followed by a 'trace back process', as parliamentary documents have dossier numbers that link to older documents in the same series. That made it possible to find documents about onshore CCS demonstration projects before the location Barendrecht was mentioned. All relevant documents of Parliament on Barendrecht were coded in NVivo10 (2012), and were searched for keywords. Based on preliminary findings we chose the keywords 'demonstration', 'pilot' and 'experiment (in Dutch: 'demonstratie', 'pilot' and 'proef' or 'experiment') in relation to the project.

Finally, we conducted 8 semi-structured interviews with persons from different stakeholders who were closely involved in the Barendrecht project, to complete the event analysis and to verify the most important events. Shell as well as the national government and the regional administration made their own evaluations of the project. These evaluations are confidential. However, we have interviewed the persons involved in these evaluations, which also have been taken into account. Moreover, we sent draft versions of our study to 6 key stakeholders, whom overall supported the analysis.

6.4. Background of the Barendrecht project

The Netherlands developed an interest in CCS during the 1990's. It took until the mid-2000's before the first projects were realised, which included an offshore storage pilot project and the delivery of CO_2 to greenhouses by Shell (Economic affairs, 2009b). The Dutch CO_2 storage capacity in small gas fields is roughly equally distributed between onshore and offshore (TNO, 2007). Since an offshore demonstration project was already successfully realised in the Netherlands and because onshore storage is in general less expensive, a strong preference for new onshore demonstration projects was expressed by the government (SenterNovem, 2008). Therefore, the national government tendered for two CO_2 storage demonstration projects in 2007 with a payment of € 30 million each (Economic affairs, 2007). The selection process was to take place through a negotiated tender procedure (SenterNovem, 2008). The actual choice of the (onshore) location was left to the applicants.

The tender was confidential. As such, only the two applicants that won the tender are known. DSM AGRO was one of the winning contenders. In this project it was planned to inject CO_2 that was generated from an ammonia plant in the South of the Netherlands into an aquifer below the plant. This project was far less developed compared to the Barendrecht project. For instance, a preliminary Environmental Impact Assessment was not performed, and the project was cancelled due to financial issues before it raised significant public interest. The Barendrecht project of Shell was the other granted application.

Barendrecht is a small town with approximately 44.000 inhabitants. It is located in the vicinity of the Port of Rotterdam. The population has a relatively high proportion of families with young children (Brunsting et al., 2011a). During the national elections in 2006 and 2010 the population had a tendency to vote slightly more for parties with a Christian tradition and significantly less for parties at the left side of the political spectrum (Electoral council, 2014). During the project the town council consisted of political parties that were all represented in the national Parliament. The (non-elected) major was a member of a small Christian party (SGP), whereas the alderman responsible for the CO_2 storage project was a member of the liberal party (VVD) (see section 6.A for more information on political parties in the Netherlands). It is important to note that several major infrastructural projects, like expansion of a highway and realisation of the Betuwe cargo railroad were executed in the area just prior to the CO_2 storage project, which may have sparked the intense local opposition that arose in later stages (Feenstra et al., 2010).

A Shell refinery is located in the Port of Rotterdam 20 kilometres from Barendrecht and has a hydrogen production facility that produces 1 megatonne (Mt) of nearly pure CO_2 annually (Shell, 2008a). Part of the generated CO_2 is sold to greenhouses and delivered by pipeline. In winter, when the CO_2 demand from these greenhouses is low, CO_2 is vented from the facility (Shell, 2008a). The storage project proposed to start with injection of CO_2 in the Barendrecht field, as a daughter company of Shell had been extracting natural gas below the village of Barendrecht since 1997 (Shell, 2008a). This small natural gas field could be considered almost empty as the pressure was 30 bar compared to the original pressure of 174 bar, and would be filled with 0.8 Mt CO_2 in three years. The initial use of the smaller field was seen as a strong additional learning experience, as the whole life cycle of CO_2 storage, from planning to injection and abandonment of the well could be carried out in a relatively short timeframe. In the second phase, injection would take place in the larger Barendrecht Ziedewij field (Shell, 2008a). The whole project should store 10 Mt of CO_2 in total.

In short, the techno-economic conditions were perceived ideal for Barendrecht, as the CO_2 was available at low costs and produced in close vicinity. At first sight the social conditions also seemed good. In the ambitious vision of the Port of Rotterdam, a major regional employer, CCS played a vital role to become a 'CO_2 free port' (RCI, 2007a and b). Furthermore, Barendrecht inhabitants had already experience with subsurface activities as natural gas had been produced for a decade.

6.5. Event analysis

We found 86 substantive (i.e. non-procedural) documents in the parliamentary database that were related to the discussion in Parliament on the Barendrecht project. The first document dates from the beginning of 2006 (Environmental affairs, 2006), whereas the latest one is the letter from 4 November 2010 with the announcement that the project was cancelled (Economic affairs, 2010a). The Cabinet sent 41 letters to Parliament, including 16 external reports and reviews. Furthermore, 45 documents were related to the deliberation in Parliament. These included the complete transcript of 23 debates, 17 documents on resolutions and 5 letters with questions from Parliament to the Cabinet.

In the beginning of 2006 the Cabinet agreed with the owners of the Borssele nuclear power plant on a complicated deal to extend its life-span. This resulted in an extra budget of € 250 million for CO_2 reduction. The Cabinet proposed to split this budget into three similar parts for renewable energy, energy saving and CCS (Environmental affairs, 2006). At the end of 2006 the Cabinet informed Parliament about details of the Borssele deal. Concerning CCS they proposed two routes. One route focused on actual CO_2 reduction by storage of CO_2, whereas the other involved research and development. The first route should be realised through a European tender with the criteria cost effectiveness (Euro/tonne of CO_2) and learning effects. Furthermore, there was a strong preference for onshore projects. Learning effects were not restricted to technical aspects only, as improving cooperation between different stakeholders was also included as a desired effect. The projects should additionally contribute to public acceptance of the relatively new and unknown CCS technology (Economic affairs, 2006).

Members of Parliament asked several written questions about the procedure, planning and cost effectiveness of the tender. One question included the possible locations. In April 2007 the Cabinet mentioned Barendrecht and Drachten, the latter being a small town in the Northern Netherlands, as potential storage locations (Economic affairs, 2007). Shortly afterwards the project was first mentioned in a national newspaper (FD, 2007).

The selection of the projects in the tender was scheduled in December 2007 and the CO_2 injection should have started by the end of 2009. The tender procedure only addressed the extra funding of these projects by the government, but permitting requirements were not included in this procedure. Shell anticipated that in order to start the injection on time, the permit procedure should begin in 2007, thus before the decision on the tender. Accordingly, they held their first meetings with local stakeholders in Barendrecht as part of their normal outreach procedure during permitting procedures. Thus, the discussion on CCS was mostly held on a national level, and only after 2007 local debates were held.

The first public signs of local unrest could be recognised at the first public information meeting in February 2008, where 60 persons attended. Social unrest in Barendrecht was also observed by several political parties, as mentioned during a meeting with the Minister of Environmental affairs. They warned the Minister to proceed with care (Parliament, 2008a). The Minister answered that the permit procedure was pending and that the Environmental Impact Assessment would be evaluated as usual, after which the Cabinet would take its final decision (Parliament, 2008a). The second local information meeting in April 2008 was attended by 180 people and sparked much more debate (Feenstra et al., 2010). At the end of 2008, after a delay of almost one year, the tender was granted to Shell (EU, 2009).

At 15 December 2008 the first critical remarks in Parliament were made when a member of the green party (GL) asked written questions about the risks, public acceptance and the choice of the location (Parliament, 2008b).

In February 2009, approximately 1000 people attended the third information meeting in Barendrecht (Feenstra et al., 2010). In March 2009 a socialist Member of Parliament (SP) expressed more critical remarks, which marked the beginning of the oral debate in Parliament.

He asked the Minister of Environmental Affairs to take the concerns of the local population seriously and to act accordingly by cancelling the Barendrecht project (Parliament, 2009b). He argued that the local protests were not only driven by self-interest, but that the residents disagreed with the concept of CCS. He furthermore stated that his party also rejected the concept of CCS, as this technology requires a lot of energy, whereas energy saving should be a top priority of the government. The Minister answered that she took the concerns of the population seriously. However, she provisionally accepted Shells choice of Barendrecht as a technically optimal location, although she repeated that the final permission depended on the judgment of the Commission on Environmental Impact Assessment. The Minister also announced that the Cabinet would take its final decision in June 2009 in collaboration with the local and regional authorities. In the same meeting a member of a small Christian party (CU) also argued that the protests by the local residents were not simply driven by self-interest. She pointed at the absence of a general selection procedure for the location. The Minister replied that studies showed that Barendrecht was the best choice (Parliament, 2009b). The Commission on Environmental Impact Assessment decided in April 2009 that the Environmental Impact Assessment (EIA) contained all the relevant information and that the external risk of the project was in accordance with Dutch law on industrial activities. According to the Commission the choice of location by Shell had been guided by sufficient consideration of the environmental aspects, given the framework of the tender (NCEA, 2009). In the same period a website was launched with general information on CCS by the government and an information centre was opened in Barendrecht by Shell.

In September 2009 the Minister of Economic Affairs informed Parliament about pending additional research on risks, stress-related health effects and alternative storage locations. She also announced a letter in which the Cabinet would explain how the Barendrecht project would fit into the plans for the large-scale implementation of CCS in the Netherlands and why CCS was necessary. Finally she stated that the go/no go decision about the storage permit would be taken in close consultation with the regional administration. However, she omitted the role of the local authorities, in contrast to the commitment of her colleague of Environmental Affairs six months earlier who stated that both regional and local administration would be involved (Economic affairs, 2009c).

During the next meeting, Members of Parliament asked many critical questions about local acceptance, risks and alternative storage locations.

They emphasised that the Cabinet was facing a difficult decision in which the national benefits had to be weighed against local concerns. However, the majority of Parliament refrained from making a final judgement on the project, as they awaited the results of new studies and the final decision of the Minister. Only the largest opposition party, the socialists (SP), remained negative (Parliament, 2009e).

In September 2009 two trains collided on the contested Betuwe railroad at Barendrecht. This local event had major impact on both local and national levels. The argument of the major of Barendrecht 'that his community was already exposed to many other risks and that the storage project would be too much' received extra attention (AD, 2009). In the fall of 2009 the debate intensified as the Ministers were about to make the final decision. On 18 November 2009 the Ministers informed Parliament on their final positive decision and intention to approve the storage permit. According to the Ministers all extra studies showed that the risks were acceptable and that no alternative location with the same benefits was available onshore. According to the study of the research institute TNO offshore fields might have been suitable as well. Nonetheless, the Ministers rejected this option as the 'realisation of storage onshore was and remains starting point of the tender'. A shift to an offshore project would not generate new knowledge, would be more expensive and would delay implementation of CCS with years. Finally, they also stated that the actual offshore realisation was questionable, as it was not clear whether the owners of the particular fields were willing to participate in the project (Economic affairs, 2009a). They did, however, decide to divide the Barendrecht project into two phases. Granting the future permit of the large field was made conditional on a positive evaluation of the first phase. They also pointed out that the project was a necessary first step in preparation of a new law stating that CCS is mandatory for coal-fired power plants (Economic affairs, 2009a).

The next day the freedom party (PVV) declared its opposition to the project in a meeting with the Minister of Economic Affairs, since they acknowledged CO_2 as only 'a fertilizer for trees, but not as the cause of climate change'. One of the small Christian parties (SGP) also opposed the project. The latter questioned the necessity of the project for implementation of CCS in the Netherlands, as other European countries were now also planning demonstration projects. For the SGP the local opposition played a crucial role, because they agreed with the notion of the local community that the region already coped with risks from highways and railroads. Finally, the green party (GL) rejected the project, as they stated that no CO_2 storage project should be performed in residential areas, without a 100% safety guarantee. A liberal party (VVD) was willing to support the project on the condition that the Cabinet would support nuclear energy, which was their preferred technology for CO_2 reduction. The two largest parties of the coalition at that time, the Christian Democrats (CDA) and the Labour Party (PvdA), reluctantly still supported the project together with an opposing liberal party (D66), but requested more (financial) compensation for Barendrecht. They also strongly expressed the hope that the second phase would become obsolete after a positive first phase, allowing immediate large-scale implementation in the northern part of the Netherlands. A small Christian party (CU), which was part of the Cabinet, refrained from voicing its final judgement (Parliament, 2009g).

The Ministers visited Barendrecht in December 2009 to explain the national government's decision, resulting in a turbulent meeting in which emotional residents expressed their distrust and anger (NRC, 2009a).

Meanwhile an economic crisis had arisen in the Netherlands and the Cabinet proposed a new law to reduce the length of permit procedures for infrastructural projects, in order to boost the economy. In the Netherlands local authorities can go to court when they believe their interests are harmed by the national government. The new law proposed to eliminate these juridical steps by local authorities (Parliament, 2009c). Many Members of Parliament, including several who supported the Barendrecht project, reacted with indignation when they discovered that the Barendrecht project was included in this new regime. They considered this unfair towards Barendrecht, as it was promised at the start of the process that the project would be discussed in a proper manner with the municipality (e.g. Parliament 2009d and 2010i). According to the new law, the local government would be stealthily outmanoeuvred, rendering the national government an unreliable partner.

In January 2010 the liberal party VVD stated that they now unconditionally opposed the project, while the few remaining supporters asked for more guarantees and mitigation measures for the Barendrecht community. The CU, the smallest party of the coalition, still refrained from giving a final judgement and requested again more proof that the Barendrecht project was necessary for large-scale implementation of CCS. To even further aggravate the situation, Parliament also debated whether it was legally correct to separate the project into two parts, as the tender specified a storage of 2 Mt CO_2, whereas the storage capacity of the first field was only 0.8 Mt CO_2 (Parliament, 2010c).

Some weeks later a small majority (55%) of Parliament rejected a resolution to cancel the project. The CU still had severe doubts and filed a resolution to postpone the final decision, which was passed (Parliament, 2010a).

In February 2010 a critical event occurred, as the government had to resign because of a political deadlock on the military intervention in Afghanistan. Parliamentary elections were announced (Parliament, 2010d). It is common practice in the Netherlands that no controversial decisions are taken by the outgoing government before a new Parliament has been elected and new Ministers have been appointed (Andeweg and Irwin, 2009). The Minister of Economic Affairs confirmed that the final decision about the storage permit was put on hold as it was considered controversial (Economic affairs, 2010b).

Another important event took place shortly afterwards, since a television documentary on the risk of the project was broadcasted on national television (Zembla, 2010). Shortly after the Minister was summoned by Parliament to answer critical questions on risks, local acceptance and the necessity of the project. Moreover, several Members of Parliament, including those in favour of the project, accused the Cabinet of withholding crucial information (Parliament, 2010i). The Minister was asked to give Parliament access to an additional new report on CO_2 storage by Utrecht University, which had been commissioned by her Department. She replied that the study was neither finished nor commissioned by her, which was immediately contradicted by a Member of Parliament who read aloud the order for the report. This rendered the report instantaneously controversial, and the event was significantly covered in the media (Parliament, 2009g). Another resolution to abolish the project was proposed by Parliament, but rejected by the same small majority (55%) as the previous resolution (Parliament, 2010e). After all parties were convinced that the Minister would postpone all next steps related to the project, the debate in Parliament stopped.

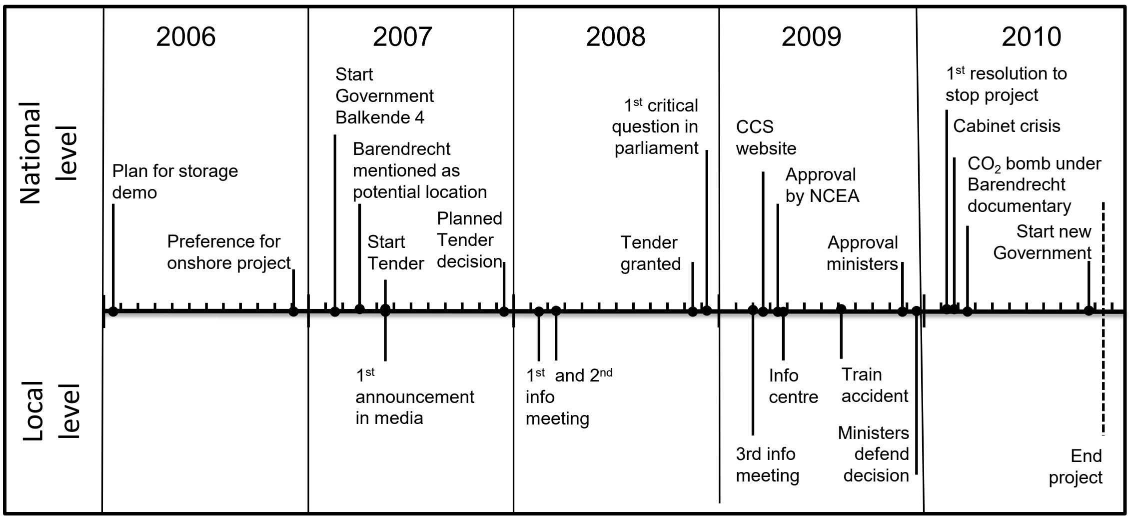


Figure 6-1 Timeline of Barendrecht project with a selection of crucial local and national events (see main text for details).

After the elections, there was no longer a majority in Parliament that supported the Barendrecht project, as all coalition parties had suffered electoral defeat. The new government, with a prominent supportive role for the climate sceptical freedom party (PVV), determined that CO_2 storage would only be allowed after granting permission for building a new nuclear power plant and under the condition of sufficient local support (VVD and CDA, 2010). Considering the very visible opposition in Barendrecht, this led to the cancellation of the project on 4 November 2010 (Economic affairs, 2010a). In Figure 6-1 the major events are summarised.

6.6. Analysis of the political debate

The debate in Parliament intensified over time. This is shown in Figure 6-2, which is based on the number of times the word 'Barendrecht' was mentioned in Parliament in the context of CCS. Before 2009 there was hardly any attention to the project in the meetings of Parliament, but this increased during the course of 2009 and the beginning of 2010. The debate was put on hold during the summer of 2010, and all decisions were postponed.

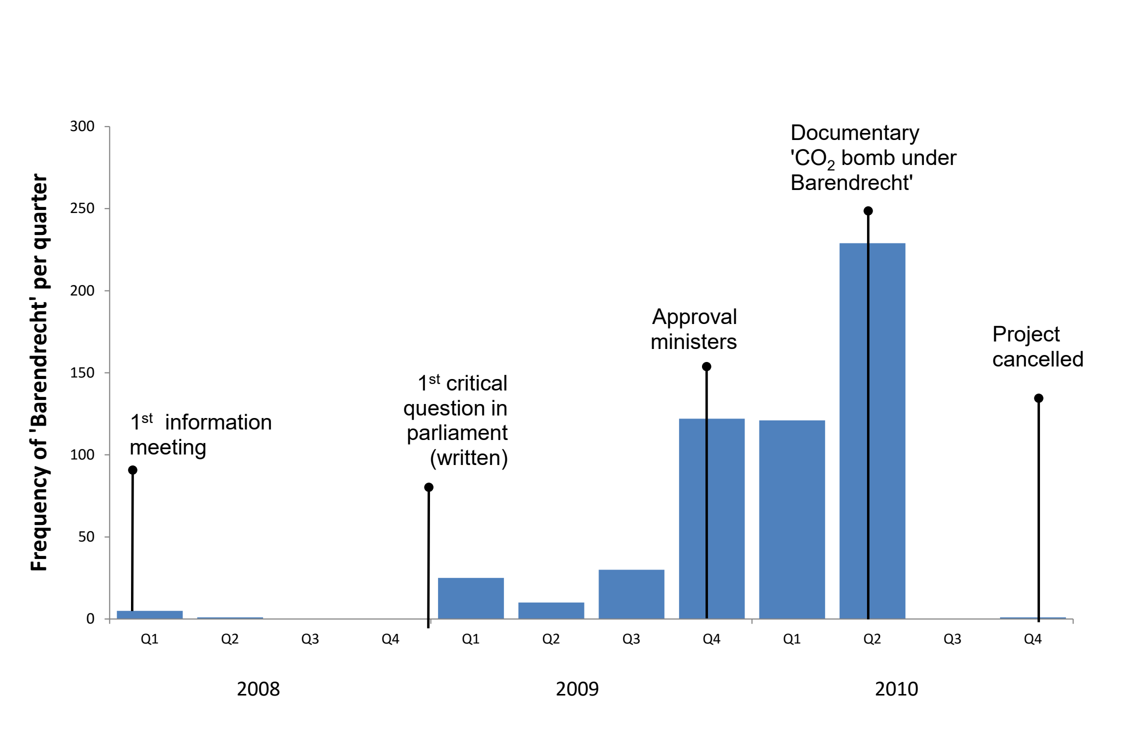


Figure 6-2 The frequency of the word 'Barendrecht' in the debates of Parliament in time. Key events are indicated. Q = Quarter. Of note, references to Barendrecht in unrelated topics have been excluded. See main text for details.

Not only did the intensity of the debate increase over time, but the tone of the debate changed as well. We observed that the words 'demonstration or pilot project' reflected a more neutral description of the project, whereas 'experiment' was mostly used in relation with risks. The population of Barendrecht was even described as 'guinea pigs' (Parliament, 2009b). We therefore searched the transcripts of debates in Parliament for these words. In 2008 the word 'experiment' related to the Barendrecht project was hardly present, but its use increased over time (Figure 6-3). In contrast the use of the words 'demonstration' or 'pilot' initially increased as the debate intensified, but were later replaced by 'experiment', which indicates the debate became more negative.

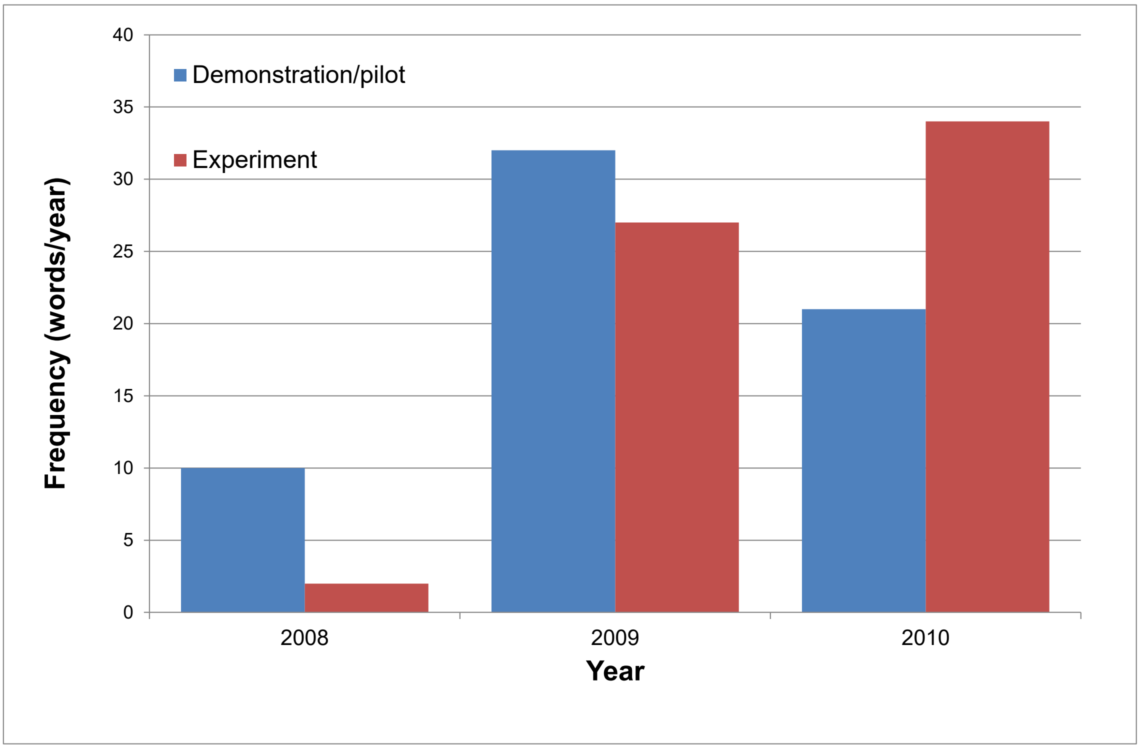


Figure 6-3 The frequency of the words 'Demonstration and pilot' versus 'Experiment' in transcripts of debates in Parliament over time, as reflection of the tone of the debate.

6.6.1. Discussions on the necessity of the project

During the discussions in Parliament the debate repeatedly focused on the conflict between necessity of the project on the one hand versus local opposition on the other hand. The necessity discussion played on three levels: the need for CCS in general, the requirement for a small demonstration project before large-scale implementation of CCS in the Netherlands and the necessity of Barendrecht as location.

Discussions on the need of CCS in general

Several policy documents presented CCS as an option to reduce CO_2 emissions before the Barendrecht project was mentioned. CCS as possibility was almost never debated. However, when CCS became a real choice in actual projects, political discussions started. Kuijper (2011) therefore stated that lack of discussion must not be confused with consensus. It was not surprising that the climate sceptical freedom party (PVV) rejected CCS. When the discussion proceeded, it became apparent that the largest opposing party (SP) rejected the concept of CCS on principle as well (Parliament, 2009b). Furthermore, once the discussion broadened, the VVD used CCS as a bargaining chip for their nuclear energy preference (Parliament, 2009g). After four years of deliberation even the supporters of Barendrecht in Parliament referred to CCS as ‘a necessary evil’ (e.g. Parliament, 2010c, 2010f).

An additional complication in the debate on Barendrecht was that the project was framed as a necessary step for large-scale CCS implementation at controversial and new coal-fired power plants. Consequently, the tight link between CCS and contentious coal-fired power plants negatively influenced the acceptance of CCS in Parliament. For example, the VVD ultimately rejected Barendrecht on the premises that they did not accept the obligation for CCS at coal-fired power plants (Parliament, 2010c). Remarkably, in spite of the cancellation of Barendrecht, new coal-fired power plants have been built without CCS, which was not contented by the new government. Thus, we conclude that there was no broad consensus on the need for CCS in the Netherlands in Parliament.

Discussions on the need of a small demonstration project

There was disagreement whether the Barendrecht project was necessary for large-scale implementation. This discussion was initiated by the CU that was part of the coalition. The government postponed and delayed the project several times, whereas the number of planned CCS projects outside the Netherlands increased. This triggered the discussion whether the Barendrecht project was really indispensable from a knowledge perspective. The project was divided in two parts, which actually resulted in a 90% reduction of CO_2 storage in the first part. This consequently raised questions about the legitimacy of the adjusted project as the specifications did not meet the tender anymore.

After discussions on risks became more intense, the government attempted to alleviate concerns by framing CCS as a safe and well-known technology. The aim of the project therefore gradually shifted towards lessons on cost estimation and procedures on permits. Although these aims are equally important compared to technical lessons to ensure large-scale implementation (Economic affairs, 2006), Parliament perceived these issues as less important and easier to reach in a different manner without burdening the population of Barendrecht. In addition, several lessons on cost calculation and juridical procedures in the Barendrecht project had already been established, which was the second reason for the new Cabinet to stop the project (Economic affairs, 2010a). Concluding, the Parliament finally judged that the added value of the continuation of the project was too small.

Discussions on the necessity of Barendrecht as location

In the end the discussion revolved mostly about the question why the location of Barendrecht was chosen. Gradually the political arena – including the government and the Committee on Environmental Impact Assessment as an independent advisor – were convinced that Shell selected Barendrecht based on the location of their own natural gas fields. As such, a national assessment for a storage location was lacking. It seems that at the start of the tender nobody realised that this procedure could lead to an issue of justifying the choice of location. To defend the Barendrecht location afterwards, a report was written about alternative locations. The inventory of locations showed that Barendrecht was indeed the best onshore location (Economic Affairs, 2009a). However, this conclusion was not very convincing in the heat of the debate and the question 'why not offshore' remained. Parliament considered the view of the local community that Barendrecht already had its fair share of large infrastructural projects with corresponding risks as reasonable. The argument of Barendrecht became even more valid when two trains collided at Barendrecht in 2009 on the contested Betuwe railroad (AD, 2009).

We therefore conclude that Parliament had doubts about all three levels of necessity of the project, thus on the need for CCS in the Netherlands, the requirement for a demonstration project for large-scale implementation and the necessity of Barendrecht as location.

6.6.2. The role of local opposition

The lack of local support played an important role in the deliberation in Parliament. Due to the local opposition the project triggered the debate and was placed on the national political agenda.

Nevertheless, Parliament was very careful about accepting local opposition driven by self-interest as a legitimate argument. A typical example occurred during a debate on a resolution that proposed to cancel the Barendrecht project. The resolution considered the lack of local support as a justified reason to reject the project. This was contested by a Member of Parliament (who opposed the project as well), as according to this line of reasoning nothing could ever be built anymore in the Netherlands. The submitter of the resolution subsequently called it 'a slip of the pen' and amended the resolution (Parliament, 2010c).

In literature there has been a lot of discussion on the concept of 'Not In My Back Yard' (NIMBY) as the name indicates that local opposition is strictly driven by self-interest. However, this is an oversimplification, as other factors may explain local opposition as well (Burningham, 2000; Devine-Wright, 2005). Wolsink (2007) therefore proposed four different types of NIMBY that provide more insight in the motivation for rejecting a local project. When applied to Barendrecht this leads to the following classification:

- NIMBY type 1: Positive attitude towards CCS combined with a negative attitude to a project in your own neighbourhood.
- NIMBY type 2: Negative attitude towards CCS and therefore also a negative attitude to a project in your own neighbourhood.
- NIMBY type 3: Positive attitude towards CCS, which changes into a negative attitude when a project is proposed in your own neighbourhood.
- NIMBY type 4: Negative attitude towards the specific project, as it is perceived as faulty in itself, without rejecting CCS as concept.

Probably all four types of NIMBY were present in Barendrecht. As illustrated with the above mentioned example of 'slip of the pen', national politicians are reluctant to accept argumentation based on Type 1, as this classical NIMBY is motivated by self-interest. The local government therefore argued that the protest was not driven by self-interest, but that this specific project was faulty (Barendrecht, 2009). In other words, they did not recognise themselves in NIMBY Type 1 but in Type 4. The local protest group 'CO_2=NEE', followed a different line of argumentation to convince that they should not be classified as Type 1, either. Their web-based petition was titled 'no CO_2 storage in Barendrecht and the rest of the Netherlands', which is more in line with NIMBY Type 2 or 3 (Petities.nl, 2013).

The political parties used the local opposition to strengthen their own reasoning. For example, the SP and PVV rejected CCS, and perceived the local opposition (NIMBY types 2 and 3) as justification for their views. The GL and SGP considered the local opposition more as NIMBY type 4. The lack of local support also required a stronger burden of proof to justify the project, as the SGP remarked (Parliament, 2009g). This resulted in a more critical approach from the Parliament towards the project and the Cabinet.

6.6.3. The role of other stakeholders

Besides the influence of local communities, the Netherlands have a long tradition of involvement of interest groups in policymaking processes (Andeweg and Irwin, 2009). In this section the role of NGOs, energy companies, regional stakeholders and scientists is discussed as well as the contribution of Shell.

Stakeholders play an important role in lobbying. Moreover, they can influence public opinion and trust by conveying their message (ter Mors et al. 2010). In May 2007, Dutch environmental organisations and labour unions presented a study on a green energy plan for the Netherlands (Green4sure, 2007). This plan aimed to reduce CO_2 emission by 50% in 2030 compared to 1990, to be realised through energy saving, renewable energy and CCS. The report mentioned mixed feelings on the concept of CCS by the environmental organisations. Nonetheless, it was agreed that halting climate change was so important that CCS should not be excluded. After 2008 Greenpeace became increasingly critical concerning CCS because, in their view, it was used as a justification to build new coal-fired power plants (Greenpeace, 2008a). During the public debate on Barendrecht the environmental organisations were almost completely absent, although Greenpeace used the media interest on Barendrecht to emphasise their opinion on coal-fired power plants. Thus, we conclude that the NGOs did not play a major role in the Barendrecht project or the debate, despite the fact that the project was framed as an environmentally friendly project.

Almost all major Dutch energy companies considered CCS as an important option to reduce CO_2 emissions, but they did not make any public statements on the Barendrecht project. In September 2009 an open letter was sent to Parliament calling for a strong policy supporting large-scale implementation of CCS. Over thirty persons, including almost all CEOs of energy companies and research institutes as well as several leading scientists, signed this letter (NRC, 2009c). The letter did not specifically refer to the Barendrecht project.

As mentioned before, CCS was an important part of the climate strategy of the Port of Rotterdam. The focus of the Rotterdam Climate Initiative (RCI) was offshore storage, which seems logical for a harbour. They therefore promoted the concept of CCS, but did not explicitly support the Barendrecht project. Mr Lubbers, former Prime Minister of the Netherlands and ambassador of the RCI, was an exception (e.g. NRC, 2008).

Scientists that supported CCS were largely invisible in the public debate on the Barendrecht project. Most of them participated in the Dutch CCS research programme CATO. It was thoroughly discussed whether the programme should join the public debate. However, the participants were reluctant to voice their opinion in the media, since it was deemed important to maintain an impartial position (van Egmond et al. 2012). In juxtaposition to the relative silence of CCS proponents, a handful of scientists that strongly opposed the project were very visible in the public debate, and received ample media coverage. For instance, professor de Jong referred to CO_2 storage in Barendrecht as 'an irresponsible experiment' (NRC, 2009b). Additionally, professor Schuiling criticised the concept of CCS, and proposed an alternative solution to sequestrate CO_2 in rocks. The public and media accepted the alternative views as credible. Consequently, more than 80% of the local Barendrecht population had the impression that scientists disagreed on safety and necessity of the project (Terwel et al. 2012).

One of the contributing factors of the Barendrecht failure was the lack of alignment between Shell and the national government (Ashworth et al. 2012). This may have been due to the (perceived) unclear responsibility of either party. Shell felt they were doing the government a favour and expected governmental support, which turned out disappointing (Kuijper, 2011). The government initially framed the tender as an invitation to industry to realise storage projects. However, in later debates Shell is referred to as the initiator, implying more responsibility for Shell. After February 2010 the government started to perceive Shell as a potential opponent instead of a partner, because of the risk of financial claims by Shell. In short, Shell and the government did not operate as a team, resulting in a faltering approach of the project. The local community viewed the project as a Shell initiative, which hampered the credibility of the project (Feenstra et al., 2010). Oltra et al. (2012) pointed out that CCS projects led by research organizations are likely to be perceived as more credible by the local population than projects led by industry.

The lack of full internal support in both parties may have played a role as well. The senior management of Royal Dutch Shell plc was committed to CCS (e.g. Shell, 2008b) and the project team of Shell Storage BV was clearly devoted, but based on our interviews we question whether the whole company favoured the project. This is illustrated by the remark of Kuijper (2011) that 'acceptance within the company can also be a challenge and should not be forgotten'. Similarly, full support inside the government was lacking, and the two Departments that were involved in the project had their own agendas on energy policy. For instance, the Department of Economic Affairs, which housed the governmental CCS project team, in fact favoured nuclear energy. The small size of the team that had to deal with all CCS issues, including Barendrecht futher suggests lack of priority.

In conclusion, large groups of professionals, including environmental organisations and scientists, shared the opinion that CCS was an important option to mitigate climate change. However, this message was hardly voiced in public. When they advocated CCS in public, mainly the concept of CCS was addressed, but the specific Barendrecht project was barely mentioned. They therefore played a minor role in convincing the local community and Parliament of both necessity and safety of the project. Furthermore, both the discord between Shell and the government, and lack of full internal support, resulted in indecisiveness and diminished credibility of the project.

6.6.4. Other issues

Besides the influence of local and national stakeholders, also the internal dynamic in the policy making process played a role as the Cabinet made some serious mistakes. For instance, it was accused of misinforming Parliament about the Barendrecht project by keeping a critical report secret. Furthermore, the credibility of the Cabinet considerably decreased due to the inclusion of the Barendrecht project in the new, shorter permitting procedures, which eliminated the possibilities of local authorities to appeal the project in court. These inaccuracies by the Cabinet caused an even more critical attitude of Parliament towards the Cabinet.

The general reduction of interest in climate change was a last factor that contributed to the cancellation of the project. The final decision was postponed repeatedly to meet demands to demonstrate necessity and safety of the project. In the four years of deliberations, the political landscape changed. In the fall of 2006 Al Gore’s 'An Inconvenient Truth' had a huge impact and climate change was an important issue for the government and society, evidenced by an increase in the number of newspaper articles on climate change, and concerns of the public on the environment. In 2010, the climate sceptical PVV gained popularity, resulting in a significant increase in the number of seats in Parliament, and overall the importance of climate change on the political agenda decreased dramatically. For example, the VVD demanded an independent assessment on the reliability of the Intergovernmental Panel on Climate Change (IPCC), before spending any more money on climate change mitigation (Parliament, 2010g).

6.7. Conclusion and discussion

By studying the local and national dynamics of the Barendrecht CCS demonstration project, we showed how the local opposition triggered the national Parliamentary debate on CCS. At the time that the national government decided to have onshore CCS demonstration projects, there was neither a thorough debate in Parliament on CCS as a climate mitigation technology nor on the implementation strategy of CCS. Only after the local uprising in Barendrecht, the debate in Parliament was started. During the political debate at the national level almost everything related to CCS and Barendrecht was questioned in Parliament, ranging from the necessity of an onshore CCS demonstration project to fundamental questions of the necessity of CCS or even climate policies. This made very clear that a lack of discussion should not be interpreted as consensus. Rather, it makes clear that discussing an abstract, novel and relatively unknown technology like CCS only becomes real when a concrete implementation project is started. This resembles a hydrogen project in London (Eames et al., 2006) in the way that such concrete projects may trigger questions and discussions that didn’t surface before.

We see in this case that Shell and the national government, took a techno-economic approach to the demonstration project. This didn’t resound with the local community at all, where a more social and local perspective prevailed. This difference in starting points made communication between the national and local level difficult, as could for instance be witnessed in a meeting with the Ministers in Barendrecht in 2009. In the debate, the supporters of CCS outside the project remained silent. The opponents were by contrast very visible, resulting in a negative attitude towards the project. Also in Parliament, the (potential) supporters of CCS remained relatively silent (Chapter 4). The conservative liberals withdrew support because they linked it to compulsory CCS for (new) coal-fired power plants. The greens also didn’t like the link with coal-fired power plants as they preferred stimulating renewable energy sources. We also saw that NGOs and scientists stayed outside the debate (Chapter 5) except for a few opposing scientists.

In the end the momentum was lost due to the multiple postponements of the project, while the perceived sense of urgency for climate change measures declined in society at large. Finally, credibility of the arguments of the local opposition increased after the government made some mistakes with the implementation of the project. Hence, Parliament demanded more proof of the national benefits of the project before it would overrule local opposition. At the end of four years of deliberating, almost everything related to CCS and Barendrecht was questioned by the public and in Parliament. Extra information was demanded over and over again, resulting in repeated postponement of the decision, which is a typical example of an arena strategy used by opponents (Devos et al., 2012). We conclude that any enthusiasm for the project had vanished after four years of debates and controversies, and even initial supporters of the Barendrecht project considered it a lost cause.

The local opposition played an important role in triggering the national debate. But if we look at the content of the debate in Barendrecht and the debate in Parliament, we see that the two seem unrelated. The local debate is driven by risk perceptions and values, while in the national debate techno-economic arguments also played an important role. Ultimately it was the lack of necessity as seen by Parliament that led to the cancellation of the project. The cancellation of the Barendrecht project had consequences for other CCS projects as well. It led to an official ban for all onshore CO_2 storage in the Netherlands, thereby reducing the storage potential significantly. Moreover, as offshore activities are in general more expensive compared to onshore activities, it is likely that this ban will increase the costs of CCS implementation.

6.A. Annex: Background Dutch national political system

The Netherlands have a multi-party political system. In general, about ten parties have seats in Parliament. To provide some understanding for non-Dutchmen on the party system, we divided them into families. The Christian parties are subdivided into the Christian Democrats (CDA), which is the largest Christian party and has a longstanding tradition in governing the Netherlands. The other members of this family consist of two smaller Christian parties: CU and SGP. Within the liberal family two parties are represented in Parliament, namely the VVD, which is the largest and D66. There are also two parties with a socialist background. The Labour Party (PvdA) has ample experience in governing, whereas the smaller SP is part of the national opposition as of yet. The Green Party (GL) focuses on social and environmental issues. The freedom party (PVV) has registered as a political party only since 2006 (Andeweg and Irwin, 2009). In Table 6-1 official names, abbreviations and number of seats in Parliament are provided.

An important characteristic of the Dutch political system is the nationwide proportional representation in Parliament. Hence there is no geographical representation, but Members of Parliament are elected based on membership of a political party and not on regional identification (Andeweg and Irwin, 2009). As Barendrecht is a small town, populated by about 0.25% of the Dutch population, the impact on national elections is thus very small.

Furthermore, the Dutch political system is dualistic and separated into the Cabinet and the Parliament with distinctive roles and responsibilities.

The Dutch Parliament consists of two chambers. Despite its name, the First Chamber is secondary in importance to the directly elected Second Chamber, which is the real political forum. The First Chamber lacks the right to initiate and amend bills, and its primary role is final evaluation of consistency of new laws (Andeweg and Irwin, 2009). The First Chamber will only be involved once legislation has been passed in the Second Chamber. Because the Barendrecht project was prematurely cancelled, it was not addressed in the First Chamber. Hence, in this manuscript we use the term Parliament to refer to the Second Chamber only, as the source of the debates.

Dutch abbreviation	Translated full name	Seats in Parliament 2006	Seats in Parliament 2010
CDA	Christian Democratic Appeal	**27%**	**14%**
PvdA	Labour Party	**22%**	20%
SP	Socialist Party	17%	10%
VVD	People's Party for Freedom and Democracy	15%	**21%**
PVV	Freedom party	6%	16%[a]
GL	GreenLeft	5%	7%
CU	Christian Union	**4%**	3%
D66	Democrats 66	2%	7%
SGP	Reformed Political Party	1%	1%
PvdD	Party for the Animals	1%	1%

Table 6-1 Description and names of most prominent Dutch political parties. Description and names adopted from Andeweg and Irwin (2009) and Woerdman (2013); seats (%) in Parliament calculated from Leiden University (2013). The percentages printed in bold indicate that the party was part of the Cabinet.
[a] The Freedom Party was formally not part of the Cabinet, but it had a special status.

During regular committee meetings Parliament and the Ministers meet and discuss amongst others energy topics. In the case of disagreements, the Parliament can ask for extra clarifications or modifications of the policy. When (part of) Parliament cannot persuade the Minister, they can vote on a resolution. Acceptance of a resolution by Parliament represents a very strong lever to implement the requested changes. If the Minister remains reluctant to conform to Parliament, it has the option to dismiss the Minister as a last resort (Bovend'Eert and Kummeling, 2010).

The Cabinet (core-executive) is formed through a coalition of at least two parties as no party in history was sufficiently large to have a majority in Parliament. The Ministers are part of the Cabinet, but are not Members of Parliament. This separation is also visible in the layout of the room where deliberations are held, as the Cabinet (Ministers) sits in a separate part of the room (Bovend'Eert and Kummeling, 2010).

Departments are managed by Ministers. In the Netherlands each department is largely autonomous. Consequently, each department has its own culture, resulting in its own preference for specific policy instruments (Andeweg and Irwin, 2009). The Department of Housing, Spatial Planning and the Environment has a long tradition of interest in CCS as part of climate change policy. The Netherlands do not have a Department for Energy. This topic is part of the Department of Economic Affairs, which focuses traditionally on affordable and reliable energy, and is involved in energy extraction policies and procedures. Both departments were involved in the Barendrecht project, but ultimately the Minister of Economic Affairs was responsible for the storage permit.

7. Conclusions and recommendations

7.1. Conclusions from the chapters

This thesis focuses on the debate on Carbon Capture and Storage (CCS) technology. CCS has been identified by many energy scenarios as an important technology to reduce CO_2 emissions in order to avoid dangerous climate change (IEA, 2013a; WEC, 2013). Nevertheless, CCS is contested and there is a public debate whether and how CCS should be implemented. Moreover, clear incentives for the implementation of CCS are lacking (IEA, 2013b). The actual implementation of CCS is therefore advancing very slowly (Scott et al., 2013). Unravelling the underlying motives will facilitate CCS development as a societally more acceptable technology. In this thesis I examine how CCS is perceived by the general public and by policy makers in the Netherlands, in order to find explanations why implementation of CCS is hampered. This thesis adds to the theoretical knowledge by showing how the views, actions and underlying motifs of the general public (chapter 3), the government and political parties (chapter 4 and 6), and the research community (chapter 5) have influenced the development of the CCS technology in the Netherlands.

The main question of this thesis was: How is CCS perceived by different actors in society and how does their opinion influence CCS development and implementation in the Netherlands?

In order to answer this question, I elaborated on different aspects of this question in this thesis. In chapter 2 we presented an overview of all arguments that are used in favour and against CCS. This chapter helps to elucidate the societal debate about CCS. In chapter 3 we investigated which of these arguments are considered persuasive, important or new by the general public. This helps to understand how the public opinion is formed and possibly how it can be influenced. In chapter 4 we made an in-depth investigation of the opinions and positions of the Dutch political parties with regard to CCS. In chapter 5 we investigated how the CATO research programmes added to knowledge development on CCS and how the researchers interacted with the societal debate. Finally, in chapter 6 the CO_2 storage project in Barendrecht is described, as this actual case study integrates all aspects described in the previous chapters. Here we examined the influence of local opposition towards a CCS demonstration project on the national political debate on CCS. Before drawing general conclusions I first shortly summarise the findings of these chapters.

Chapter 2 provides an inventory of all arguments in favour or against CCS. Such an in-depth overview of arguments in favour or against CCS, and their scope, may contribute to a better-informed and balanced deliberation on the necessity and desirability of CCS as a climate mitigation technique. CCS is an umbrella term for different configurations of separate technologies. A CCS chain consists of three steps, namely capture, transport and storage. Each step has one or more elements, which contain several components (see Figure 2-2). The combination of these components results in an integrated CCS project. For instance, in Shell's proposed Barendrecht project the hydrogen production from natural gas at a refinery comprised the capture step, after which CO_2 should be transported by pipeline. In the final storage step CO_2 would be stored in an empty gas field at Barendrecht. We estimated that there are approximately 500 different logical CCS chains, which each have their own advantages and drawbacks.

The overview of the arguments on CCS is based on workshops in which Dutch stakeholders participated (Argumentenfabriek, 2010). We found 57 unique arguments that could be divided in 31 arguments against and 26 arguments in favour of CCS. The arguments were divided into six categories: Climate, Energy, Environment, Ethics, Safety and Economics, and were presented as an 'Arguments map'. We found that some arguments (24) apply to all CCS chains, whereas others relate to a particular configuration only (33). We also found that some arguments can help to direct future CCS research. For instance, the argument that CCS costs a lot of extra energy is applicable for the power sector, but less so for natural gas treatment. Development of more efficient capture technologies may counterbalance the negative impact of CCS in the power sector. The Arguments map may therefore help the CCS community and policy makers to guide their considerations on future energy systems, and about the suitability of different CCS chains.

We determined the persuasiveness, importance and novelty of the arguments for the Dutch general public in chapter 3. The results of a survey are presented in which the Dutch public assessed a selection of 32 arguments (based on the Arguments map from chapter 2). We used a discrete choice experiment in which respondents made consecutive choices between pairs of pro or con arguments. The respondents either received pro or con arguments. The most important argument in favour of CCS was: 'CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions'. Arguments related to climate change proved to be relatively unpersuasive for the public, even though climate protection is the primary goal of CCS. Instead the public prefers norm or value-based arguments. For instance, the norm that ‘A waste product such as CO_2 should be disposed of properly’ was perceived as a persuasive argument for CCS. Similarly, the most convincing and important argument against CCS appeals to a norm as well: ‘it is better to avoid generating CO_2 than to store the CO_2’. The respondents to the pro arguments could be clustered into 3 segments of similar size (approximately 32-34%), based on their choices, although differences between the clusters were small. Respondents to the con arguments could be divided into two segments. A vast majority of 82% of the respondents to con arguments agreed on the most persuasive argument (‘It is better to avoid generating CO_2 than to store CO_2’). A cluster of 18% chose arguments related to risks. We additionally examined whether the arguments to which individuals were exposed changed their attitude towards CCS, as this gives an opportunity for development of improved communication and implementation strategies. Before exposure the average attitude score of the general public was neutral. Exposure to only pro arguments slightly changed opinions in favour of CCS, whereas exposure to only con arguments had a negative effect. Thus, it is possible to influence the attitude of a lay public through communication of arguments on CCS. The effect of exposure to negative arguments was somewhat higher compared to exposure to arguments in favour of CCS. Thus, only improving the knowledge of the general public on CCS will not necessarily lead to higher acceptance of CCS, which is in line with previous findings (Anable et al., 2006). Furthermore, this suggests that opponents can more easily influence public opinion than supporters of CCS.

We next investigated the debate on CCS in the Dutch Parliament (chapter 4). We related political ideologies of the different parties to their positions on CCS. There was a large variety of opinions in the Dutch Parliament, ranging from complete rejection, conditional rejection, conditional acceptance, to acceptance. One of my main findings indicates that the implementation of CCS in the Netherlands did not fail because of strong opposition, but due to a lack of sufficient supporters. Whereas the pro arguments in Parliament mostly clustered on climate change, a multitude of different arguments against CCS was found. The argument of ‘energy cost for CO_2 capture’ was frequently mentioned as a drawback of CCS as well as ‘competition of CCS with implementation of renewable energy’. Additionally, CCS was often labelled as ‘an end of pipe solution with no actual CO_2 emission reductions’, which was perceived as a major disadvantage. The safety of CCS was a minor issue in Parliament. The lack of local support, partly due to perceived risks by the local population, however, did influence the debate in Parliament.

To clarify the positions of the individual parties, we proposed a conceptual model in which the goal of CCS, namely CO_2 reductions, and CCS as a method to reach this goal, are separated. Four groups could be defined. Left wing progressive parties tend to accept the goal of CCS, but prefer renewable energy as a method to reduce CO_2 emissions. These are classified as Conditional Opponents. The CCS technology fits with right wing conservative parties, but given their lower climate ambition they do not feel the need for extra CCS policy, making them Conditional Supporters. Right wing progressive parties are Unconditional Supporters, which are already in favour of both the goal and method of CCS. Left wing conservative parties (Unconditional Opponents) decline both the goal and the method. Currently, in Dutch Parliament only one party (D66) makes up for the Unconditional Supporters. As such, it is unlikely that CCS will be implemented in the Netherlands soon, unless more support is generated. This may be achieved with better and targeted communication. Conditional Opponents and Supporters currently comprise the majority in Dutch Parliament and accept either the goal or method of CCS. As such, they represent the target audience to gain support. To convince Conditional Opponents it is necessary to position CCS as an acceptable method without threatening their desired sustainable energy system. Conditional Supporters will be more easily persuaded by arguments related to techno-economical aspects like the increased cost-effectiveness of climate change mitigation portfolios if CCS is included.

As both public opinion and policy making is influenced by scientific findings, we address the relationship between science and society in chapter 5. This chapter focuses on the CATO programme, which is the Dutch research programme on CCS. We showed that the Dutch knowledge base is among the frontrunners worldwide. We also showed that actual demonstration projects are essential to foster cooperation between different areas of expertise and to generate interest of important stakeholders, including industry, policy makers, media and the public. Moreover, prospects of such projects drive the direction of the natural and social science research as well as the public debate. Industrial partners had a strong influence on the design of the research agenda of the programme, due to the earmarking process of the budget. Consequently, a large part of CATO focused on deployment, and the capture part was mostly related to coal-fired power plants. Because of this focus some NGOs left the consortium. The direction of CATO was furthermore strongly impacted by changes in government policy. Local opposition and media coverage increased the awareness of the importance of social science topics. CATO in turn provided useful knowledge for demonstration projects of industry, and for developing long term governmental CCS policy. The understanding of CCS by the scientific journalists significantly improved due to the communication with the programme management. Influence of CATO on the opinion of the general public was limited.

A key project that was at the start very promising, but ultimately unsuccessful and cancelled was the Barendrecht CO_2 storage project, which we describe in chapter 6. This project was initiated by the Dutch government. In this study we analysed the influence of the local public, other stakeholders and the Dutch government on the execution of the project. The local community strongly opposed the project. Multiple factors contributed to this opposition, including poor communication, distrust of Shell and the national government, lack of public engagement, the relative unfamiliarity with the technology, the perceived negative local impact, the absence of benefits for the local population and classical NIMBY effects. The local opposition played an important role in triggering the national debate in Parliament, although we saw that the content of the local debate was not always related to the type of arguments that were used in the debate at the national level. This debate ultimately resulted in cancellation of the Barendrecht storage project by the Dutch government.

The Barendrecht project is not unique. Quite often the national government initiates and decides on large infrastructural projects in which local opposition has to be weighed against national benefits. In many cases national benefits are deemed more important. We showed that the opinion of the national government regarding the Barendrecht project changed over time. Consensus on the necessity of CCS was assumed by the Dutch government at the start of the project. However, as well CCS as a climate mitigation strategy, as its implementation and storage locations became contested in Parliament due to intensified local opposition. The lack of solid outside support and the strong views of local opponents led to a changing balance in the debate. Additionally, momentum was lost due to multiple delays, which also ended enthusiasm of the initial supporters. Consequently, the project was cancelled.

Several lessons can be learned from the processes and debates that relate to the Barendrecht storage project. This knowledge may help to avoid similar issues that threaten future large infrastructural projects. First, national support should be ascertained instead of presumed prior to the start of a project. Second, proper local implementation measures, including public engagement, well-designed communication strategies and effective compensation measures should be taken. This will reduce local opposition, although it may not be completely prevented. If local interests have been duly considered and weighed against general and national interests, the impact of local opposition may be lessened in national Parliament. Furthermore, a strong prior consensus on the necessity at the national level allows the Cabinet to make difficult decisions that overrule local opposition. The development of the Barendrecht project resembles a hydrogen project in London (Eames et al., 2006) in the way that the development of a concrete technological project may trigger questions and discussions that didn't surface before. The actual implementation of a new technology that was previously mostly treated in abstract terms suddenly necessitates looking into all the details and issues that come along with it. Prior performance of an in-depth debate, e.g. in the form of a Constructive TA may help to expose potential problems and challenges before a project is started.

7.2. Perception of actors on CCS

In the previous section I described the key findings in the chapters. In this section I will summarise the views of the different actors.

The general public has a neutral attitude towards CCS, as the majority neither rejects CCS nor embraces this technology. Although the primary goal of CCS is climate change mitigation, arguments about climate change are relatively unpersuasive to increase support for CCS. By contrast, a part of the population is in particular susceptible to arguments on risks of CCS. As seen in the Barendrecht case, the general neutral attitude towards CCS may change into rejection by the local population when a concrete project is proposed. This is mostly due to a lack of trust in the project and concerns related to risks.

In Parliament only one political party (D'66) can be seen as Unconditional Supporters of CCS. The majority of the Dutch political parties are either Conditional Supporters or Conditional Opponents of CCS. Unconditional Opponents that completely reject CCS are a minority. In Parliament the importance of climate change mitigation is most frequently used as an argument in favour of CCS, whereas this argument is perceived as relatively unpersuasive by the general public.

The safety of CCS was a minor issue in Parliament, as well as for the general public (18% of respondents (segment Con-2) in Chapter 3 considered arguments on risks persuasive). However, safety was very important to the local public, and the lack of local support influenced the debate in Parliament significantly.

The industry is reluctant to implement CCS due to the lack of incentives. Currently only one large demonstration project is being prepared. The participation of industry in research programmes like CATO nonetheless indicates their interests. As such, their attitude may change in the future, provided more incentives become available.

The opinions on CCS by NGOs are varied. Some (cautiously) support CCS, whereas Greenpeace for example rejects it, in particular when it is related to coal-fired power plants. Within the scientific CCS community CCS is deemed a necessary element in CO_2 mitigation by virtually all scientists. This probably also holds true for the majority of scientists in the energy and climate field. There are only a few scientists in these fields that reject CCS.

I conclude that there are neither large groups of pronounced supporters nor opponents of CCS. Especially the lack of supporters explains the slow implementation of CCS. Clearly the Barendrecht storage project received strong local opposition. However, local opposition is sparked by most large infrastructural or energy projects, and is not specific for CCS. Ultimately, it was the absence of strong national support for the Barendrecht project and CCS in general that resulted in the cancellation of the project. Although I often referred to CCS as a contested technology in this thesis, one can argue whether this is the correct term as there is no nationwide anti-CCS movement, which is in contrast to nuclear energy, shale gas and to a lesser extent even wind energy. From this point of view CCS can perhaps be seen as a low interest technology rather than a contested technology.

7.3. Future of CCS and recommendations

Remarkably, many actors still have high expectations for CCS as climate mitigation technology as seen in the energy scenarios in spite of the lack of strong supporters and the slow implementation of CCS (e.g. IEA, 2013b). The importance of CCS was also recognised in the Energy Deal, as CCS was considered inevitable to keep climate change within safe limits. This covenant on the future of the energy system was agreed upon by representatives of employers, labour unions and environmental organisations, which was later adopted by the Dutch government

(Economic Affairs, 2013; SER, 2013). However, besides developing a long-term CCS strategy by the government, no concrete other activities or targets were defined, as for example was done for wind energy and the closure of old coal-fired power plants. Moreover, the debate on CCS was mainly held during crises, such as Barendrecht, which negatively impacted the attitude on CCS. Before that time CCS figured in policy documents on climate change mitigation without drawing too much attention from politicians and the general public. The local opposition that grew in Barendrecht stirred the local and national debate on CCS. One can question if the national debate would have gone in a different direction if the process of selecting Barendrecht as location as well as its implementation (including proper involvement of the local population) had been handled more carefully.

CCS is currently in a deadlock. It is perceived as important, but the urgency to act is missing. Supporters of strong climate policy prefer other technologies, whereas groups that may support CCS technology lack the urgency for strong climate policy.

I see three possible ways out of this deadlock. The first lies outside the area of CCS, namely enforcing strong climate targets. When CO_2 reduction targets significantly expand, implementation of CCS is most likely essential to meet these goals in an economical manner, as projected by many scenarios. It is unlikely that the Netherlands will adopt such targets without comparable international agreements. Furthermore, the impact of the CCS community or the Dutch government to influence global climate treaties is limited. Realistically, this scenario lies mostly outside the sphere of influence of the Dutch government.

A second strategy to resolve this stalemate could be the use of targeted argumentation on CCS in order to increase support. By studying which arguments may persuade the general public we found that climate mitigation arguments were perceived as less convincing by the population. Other arguments that were related to economic aspects or were related to behavioural norms were found to be much more persuasive. It is important to notice that the non-persuasive climate arguments were generally put forward by supporters of CCS, which will have had limited effect to gain general acceptance. A further remark to this strategy is that arguments may be less persuasive when CCS projects are actually implemented close to inhabited areas.

Besides altering communication strategies to sell CCS as an acceptable technology for society, shifting actual implementation towards less controversial CCS chains represents a third option. This possibility to break the deadlock entails the design of more acceptable implementation strategies of specific CCS chains. Additionally, the Energy Deal that was agreed in 2013, in which CCS was seen as inevitable, may be extended with more detailed specific agreements on the actual implementation of CCS.

In this thesis we have identified the pro and cons of different CCS chains (Chapter 2), which may guide the next steps. Moreover, we determined the most convincing arguments for specific actors. For instance, organisations with a green and left wing orientation have in general strong climate ambitions, but reject CCS associated with coal-fired power plants. Additionally, they are concerned that CCS will interfere with the introduction of renewable energy. Development of CSS configurations that do not hamper implementation of renewable energy may increase support of these parties. By contrast, organisations with a more economical and right-wing perspective do not yet see the need for strong climate policy and consider the costs associated with CCS as the most important con argument. Thus reduction of costs may persuade these organisations, as they consider the Energy Deal too costly. Interestingly, reaching climate targets without CCS is more expensive than implementing it with CCS (ECN, 2007), which might be a convincing argument for this group.

Thus, several objections need to be removed before an agreement can be reached by all actors. Topics that need to be addressed are for instance Enhanced Oil Recovery (EOR)*,* Utilization of CO_2, Bio-Energy and CCS, CCS in industry and Coal-fired power plants.

The heart of the current problem with CCS in the Netherlands seems to be the lack of sufficient explicit supporters of CCS. Additionally, it is difficult to bridge the differences between (local) public debates, which focus on risk perceptions, versus a 'professional' debate that revolves on techno-economic arguments. This thesis provides directives to tackle these issues.

Samenvatting en conclusies

Dit proefschrift gaat over het debat rond de afvang en opslag van CO_2 (CCS) in Nederland. CCS wordt in veel energiescenario's gezien als één van de noodzakelijk technologieën om gevaarlijke klimaatverandering tegen te gaan. De feitelijke implementatie verloopt echter traag en er is een maatschappelijk debat in hoeverre deze implementatie wel wenselijk is. In dit proefschrift onderzoek ik de opinies van verschillende actoren, zoals het publiek en de politiek, en zet ik deze af tegen de ontwikkeling en implementatie van CCS. Door de onderliggende argumenten gedetailleerd te bestuderen ontstaat er inzicht in hoe de introductie van CCS, indien wenselijk, versneld kan worden. Dit proefschrift draagt bij aan de wetenschappelijke kennis hoe de opinies en onderliggende motieven van het algemeen publiek (hoofdstuk 3), de politiek (hoofdstuk 4 en 6) en de wetenschap de ontwikkeling van CCS hebben beïnvloed.

De hoofdonderzoeksvraag is: Wat is de perceptie over CCS van verschillende groepen in de maatschappij en hoe beïnvloed deze opinie de ontwikkeling en implementatie van CO_2 afvang en opslag in Nederland?

In Hoofdstuk 2 wordt eerst een overzicht gegeven van de argumenten voor en tegen CCS, op een zogenaamde 'Argumentenkaart'. CCS is een verzamelterm voor veel verschillende technologieën. Een CCS keten bestaat uit drie stappen. In de eerste stap wordt de CO_2 gescheiden van andere gassen, bijvoorbeeld uit rookgassen. Daarna wordt de CO_2 getransporteerd om tenslotte in de diepe ondergrond opgeslagen te worden. Deze stappen kunnen weer worden opgedeeld in verschillende elementen, die zelf weer uit verschillende componenten bestaan (zie figuur 1-1, pagina 16). Door verschillende componenten te combineren onstaat een CCS keten. In bijvoorbeeld het CCS project dat voor Barendrecht werd voorgesteld, wilde men de CO_2, die vrijkwam bij de productie van waterstof in een raffinaderij, per pijpleiding transporteren naar Barendrecht. Daar zou de CO_2 worden opgeslagen in een leeg aardgasveld op het vasteland. We schatten dat er ongeveer 500 verschillende logische CCS ketens kunnen worden bedacht op basis van de verschillende componenten, elk met eigen voor- en nadelen.

Er werden 57 argumenten geïdentificeerd, waarvan 31 tegen CCS en 26 voor CCS. Deze argumenten werden geclusterd in de thema's energie, klimaat, milieu, economie, ethiek en veiligheid. De meerderheid van de argumenten (33) is geldig bij specifieke CCS ketens, de overige argumenten (24) zijn generiek van toepassing op alle CCS ketens. Zo is bijvoorbeeld het argument dat CCS veel extra energie kost van toepassing bij de elektriciteitsproductie, maar niet bij het zuiveren van aardgas. In dit geval kan technologieontwikkeling het genoemde nadeel kleiner maken, door efficiëntere afvang technologieën. De argumentenkaart geeft daarom niet alleen inzicht in de voor en tegens, maar kan ook gebruikt worden om richting te geven aan technologieontwikkeling.

De inventarisatie van de argumenten laat in het midden hoe de argumenten beoordeeld worden door verschillende belanghebbenden. In hoofdstuk 3 wordt beschreven hoe belangrijk, overtuigend en nieuw de argumenten worden gevonden door het Nederlandse publiek. In een vragenlijst kregen de deelnemers telkens de keuze uit twee verschillende argumenten. Het experiment werd gedaan met een representatieve selectie van de Nederlandse bevolking. Deze selectie werd opgedeeld in twee groepen die louter argumenten voor, respectievelijk argumenten tegen CCS voorgelegd kregen. Het meest overtuigende argument was "CCS kan toegepast worden in de industrie waar alternatieven voor CO_2-reductie ontbreken". Argumenten die verwijzen naar klimaatverandering werden als minder overtuigend beoordeeld. Verder viel op dat argumenten die refereren naar een waarde of norm in het algemeen als overtuigend beoordeeld werden. Dit gold bijvoorbeeld voor het voorargument "CO_2 is een restproduct van elektriciteitsopwekking, dat hoor je niet in de lucht te lozen" en het tegenargument "Een restproduct stop je niet voor eeuwig in de grond, dat is het verschuiven van het probleem". Dit laatste argument werd door een heel groot deel (82%) van de ondervraagden als overtuigend en belangrijk beschouwd. Een kleiner segment (18%) vond argumenten met betrekking tot risico's juist overtuigend en belangrijk.

Vóór de enquête was de gemiddelde houding van de respondenten neutraal ten opzichte van CCS. Na het lezen van alleen de voorargumenten werden de respondenten iets positiever over CCS. De groep die de tegenargumenten voorgelegd kreeg werd juist negatiever; de verschuiving in de opinie van deze groep was iets groter dan de groep die alleen voorargumenten te zien kreeg.

Vervolgens hebben we het debat over CCS vanaf 1995 in de Tweede Kamer geanalyseerd in hoofdstuk 4. De verschillende politieke partijen hebben uiteenlopende opinies over CCS, van volledige afwijzing tot volledige acceptatie van CCS. Een van de belangrijkste conclusies was dat de langzame introductie van CCS niet komt door het grote aantal tegenstanders, maar door het ontbreken van voldoende overtuigende voorstanders. De argumentatie voor CCS was vooral geclusterd rond het thema klimaat. De tegenargumenten laten een breder spectrum zien. Zo werd gewezen op de extra energie die nodig is voor CCS en werd betoogd dat CCS de introductie van duurzame energie remt. De argumenten rond de veiligheid werden relatief weinig genoemd.

Om de verschillende standpunten nader te verklaren stellen we een conceptueel model voor waarin we het doel van CCS, namelijk CO_2 reductie, loskoppelen van de methode (CCS) om dit doel te halen. Dit model resulteerde in vier verschillende groepen van politieke partijen. De linkse progressieve partijen ondersteunen het doel van CCS, namelijk klimaatverandering tegengaan, maar verkiezen duurzame energie als middel om dat te bereiken boven CCS. CCS past als technologie veel beter bij de rechtse conservatieve partijen, maar deze hechten minder belang aan het doel van CCS (CO_2-emissiereductie) en voelen daarom weinig voor extra beleid om CCS te stimuleren. In dit model verwerpen conservatieve linkse partijen zowel het doel als de methode van CCS, terwijl rechts progressieve partijen juist het doel en de methode omarmen. Deze laatste groep bestaat momenteel slechts uit partij: D'66. Het is daarom onwaarschijnlijk dat CCS op grote schaal wordt geïmplementeerd, tenzij er bredere steun wordt georganiseerd. Dit zou kunnen door beter in te spelen op de onderliggende motieven van de diverse partijen. Zo heeft het weinig zin om de linkse progressieve partijen te overtuigen van het doel van CCS, maar kan gezocht worden naar mogelijkheden waarbij CCS als methode minder controversieel zou worden. Dit zou bijvoorbeeld CCS bij de industrie kunnen zijn, waarbij door het ontbreken van andere alternatieven, de bedreiging voor introductie van duurzame energie veel kleiner is. Rechts conservatieve partijen zouden kunnen worden overgehaald door op de kosteneffectiviteit van CCS te wijzen.

In hoofdstuk 5 wordt de interactie tussen wetenschappers en de maatschappij bestudeerd, en met name de rol van het nationale onderzoeksprogramma "CO_2 afvang, transport en opslag" (CATO). We constateren dat demonstratieprojecten erg belangrijk zijn voor zowel de integratie van kennis tussen CCS ketens, als voor de betrokkenheid van industrie, politiek, media en publiek bij CCS. Industriële partijen hadden veel invloed bij het opstellen van de onderzoeksagenda van CATO. Het gevolg hiervan was dat het toegepaste onderzoek zich concentreerde rond de afvang en opslag bij kolencentrales. Het overheidsbeleid, bijvoorbeeld de ban op de opslag van CO_2 onder land, beïnvloedde het programma ook aanzienlijk. De impact van CATO op de publieke opinie bleek beperkt te zijn.

Het Barendrecht project was één van de beoogde CCS demonstratieprojecten. Het werd geïnitieerd door de nationale overheid, maar werd door diezelfde overheid later ook weer gestopt. In hoofdstuk 6 analyseren we deze casus. De lokale bevolking in Barendrecht was tegen het project, onder meer vanwege gebrekkige communicatie, het wantrouwen jegens Shell, als uitvoerder van het project, en de nationale overheid. Het Barendrecht project is niet uniek. Veel vaker verzet de lokale bevolking zich tegen grote infrastructurele projecten. De beslissingsbevoegdheid van dergelijke projecten ligt echter niet op lokaal niveau, maar op nationaal niveau. We hebben laten zien dat de lokale onrust zorgde dat het project op de agenda van de Tweede Kamer kwam. Daar bleek dat de noodzaak van CCS, de noodzaak van kleine demonstratieprojecten, en de noodzaak van Barendrecht als opslaglocatie controversieel waren. Het gebrek aan positieve steun buiten de Tweede Kamer leidde tot een verschuiving in het debat. Daarnaast werd het project diverse malen uitgesteld, en werden er verscheidene fouten gemaakt waardoor het momentum langzaam verdween en de steun van de voorstanders in de kamer afbrokkelde. Dit had als gevolg dat het project uiteindelijk werd gestopt.

Een belangrijke les die getrokken kan worden, is dat het belangrijk is om voor de start van een dergelijk groot project, expliciete consensus op nationaal niveau te bereiken over de wenselijkheid en de noodzaak. Indien er dan, ondanks een zorgvuldig proces, lokale weerstand ontstaat, kan op nationaal niveau besloten worden dat nationale belangen prevaleren boven lokale zorgen.

Verschillende opinies

De Nederlandse bevolking staat neutraal tegenover CCS, er zijn geen grote groepen tegenstanders, zoals bij schaliegas en kernenergie, maar er zijn ook weinig uitgesproken voorstanders, zoals bij zonne-energie en kernenergie. Deze neutrale houding kan bij de lokale bevolking snel omslaan in een negatieve houding indien een concreet project in hun buurt wordt gepland.

In de Tweede Kamer is D’66 de enige partij die de aflopen decennia CCS onvoorwaardelijk heeft gesteund. De meeste partijen, waaronder de PvdA en CDA, accepteren CCS onder bepaalde randvoorwaarden. De minderheid, PVV en SP verwerpen CCS.

Het bedrijfsleven is terughoudend om CCS te implementeren door het gebrek aan (economische) noodzaak. Ze tonen wel interesse in CCS, wat was af te lezen uit hun betrokkenheid bij onderzoeksprogramma's, maar wachten op de noodzaak of betere mogelijkheden voordat ze overgaan tot implementatie. Er is momenteel slechts één grootschalig demonstratieproject in de planning.

De houding ten opzichte van CCS binnen de milieubeweging is divers. Sommige partijen steunen CCS, zoals WNF en Natuur en Milieu. Andere delen van de milieubeweging, zoals Greenpeace, verwerpen CCS met name als deze gekoppeld wordt aan kolencentrales. Binnen de wetenschappelijke CCS gemeenschap wordt CCS als noodzakelijk gezien om klimaatverandering tegen te gaan. Dit geldt tot op zekere hoogte ook voor het bredere veld van klimaat- en energiewetenschappers.

Conclusies en aanbevelingen

Het antwoord op de onderzoeksvraag uit dit proefschrift is het volgende: Er zijn geen grote groepen uitgesproken voorstanders of tegenstanders voor CCS. CCS wordt door velen gezien als onvermijdelijk, zoals ook is vastgelegd in het energieakkoord dat is gesloten tussen werkgevers, werknemers, milieuorganisaties en de overheid. Aan de andere kant ontbreekt de urgentie om vaart te maken met de implementatie van CCS. Voorstanders van stevig klimaatbeleid verkiezen vaak andere opties boven CCS. terwijl bij groepen waar de CCS technologie beter past, de ambitie om klimaatregelen te nemen lager is. Dit verklaart waarom er momenteel in Nederland weinig stappen worden ondernomen om CCS te implementeren.

Ik zie drie mogelijke uitwegen uit deze patstelling. De eerste ligt buiten het veld van CCS, namelijk het afspreken van hogere klimaatdoelen. De grootschalige implementatie van CCS volgt dan waarschijnlijk, omdat dit een kosteneffectieve manier is om deze doelstellingen te halen, en omdat anders de totale kosten voor het klimaatbeleid te hoog gevonden kunnen worden.

En tweede strategie is een betere en gerichte communicatie om meer voorstanders te krijgen. Het argument dat men verantwoordelijk is om zijn eigen afval en dus ook CO_2 op te ruimen is een overtuigend argument, maar wordt in de praktijk maar zelden gebruikt. Ook ontbreekt het argument dat CCS een relatief kosteneffectieve manier is om klimaatdoelstellingen te halen vaak in het debat. Er wordt daarentegen juist gesteld dat CCS veel extra kosten met zich meebrengt.

Naast het anders ‘framen’ van het debat, zie ik een verschuiving van de feitelijke implementatie naar minder controversiële CCS ketens als derde mogelijkheid. Zo is CCS bij de staalindustrie veel minder controversieel dan bij kolencentrales, en opslag onder zee minder controversieel dan opslag onder land. Er kan worden gewerkt aan een bredere consensus over welke vormen van CCS maatschappelijk gewenst zijn en onder welke voorwaarden. Hiermee wordt voorkomen dat partijen CCS in het algemeen afwijzen, terwijl de grote bezwaren feitelijk slechts bij bepaalde ketens van CCS liggen. Ketens die interessant zijn om te bespreken zijn: extra olie- en gaswinning door CCS, CCS bij kolen- en gascentrales, CCS in de industrie en CCS gecombineerd met biomassa.

Contribution of PhD candidate to manuscript

Sander van Egmond was the only author of the chapters 1 and 7 in this thesis. The chapters 2, 4, 5 and 6 are based on papers (already published or underway to be published), of which Sander van Egmond was the first author, and responsible for the design and reporting of the research. Part of the research for chapter 2 and the design of the Argument Map were executed by a third party, under the supervision of Sander van Egmond. He was the leader of the research project as reported in chapter 3 and the second author on the paper that was written on the basis of these results, as he was involved in the research design and reporting.

References

The debates in the Parliament are indicated with 'Parliament'. The date refers to the date of the meeting and not to the date of the official approval of the minutes. Letters from the Ministry of Economic Affairs or Ministry of Environmental Affairs are referred to as 'Economic affairs' or 'Environmental affairs', respectively.

AD, 2009. National daily newspaper, Barendrecht: het is nu echt, 3 October 2009.

Allenby, G.M., Rossi, P.E., 1999. Marketing models of consumer heterogeneity, Journal of Econometrics, Elsevier 89 (1-2), pages 57-78.

Alphen, K. van, Noothout, P.M., Hekkert, M.P., Turkenburg, W.C., 2010. Evaluating the development of carbon capture and storage technologies in the United States, Renewable & Sustainable Energy Reviews, 14, pages 971–986.

Anable, J., Lane, B., Kelay, T., 2006. An evidence base review of public attitudes to climate change and transport behaviour: final report, Department for Transport, London, United Kingdom.

Anderson, J., Chiavari, J., 2009. Understanding and improving NGO position on CCS, Energy Procedia 1, pages 4811–4817.

Andeweg, R.B., Irwin, G.A., 2009. Governance and Politics of the Netherlands, Palgrave Macmillan, United Kingdom.

Arentsen, M.J., 2006. Contested Technology, Nuclear Power in the Netherlands, Energy & Environment 17, No. 3.

Argumentenfabriek, 2010. Argument map CO_2 capture and storage (CCS), Amsterdam, the Netherlands.

Ashworth, P., Boughen, N., Mayhew, M., Millar, F., 2010. From research to action: Now we have to move on CCS communication, International Journal of Greenhouse Gas Control 4, pages 426-433.

Ashworth, P., Bradbury, J., Wade, S., Feenstra, C.F.J., Greenberg, S., Hund, G., Mikunda, T., 2012. What's in store: Lessons from implementing CCS, International Journal of Greenhouse Gas Control 10, pages 402-409.

Azar, C., Lindgren, K., Obersteiner, M., Riahi, K., Vuuren, D.P. van, Elzen, K.M.G.J. den., Möllersten, K., Larson, E.D., 2010. The feasibility of low CO_2 concentration targets and the role of bio-energy with carbon capture and storage (BECCS), Climatic Change, pages 195–202.

Bamberg S., Möser G., 2007. Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour, Journal of Environmental Psychology, 27(1), pages 14–25.

Barendrecht, 2009. Zienswijze MER ondergrondse opslag van CO_2 in Barendrecht, letter from Barendrecht City Council to Province Council Zuid-Holland, 23 March 2009.

Best-Waldhober, M. de, Daamen, D.D.L., Faaij, A.P.C., 2009. Informed and uninformed public opinions on CO_2 capture and storage technologies in the Netherlands, International Journal of Greenhouse Gas Control 3, pages 322–332.

Best-Waldhober, M. de, Brunsting, S., Paukovic, M., 2012a. Public concepts of CCS: Understanding of the Dutch general public and its reflection in the media, International Journal of Greenhouse Gas Control 11, pages S139–S147.

Best-Waldhober, M.de, Daamen, D.D.L., Ramirez, A.R., Faaij, A.P.C., Hendriks, C., Visser, E. de, 2012b. Informed public opinion in the Netherlands: Evaluation of CO_2 capture and storage technologies in comparison with other CO_2 mitigation options, International Journal of Greenhouse Gas Control 10, pages 169–180.

Bhat, I.K., Prakash, R., 2009. LCA of renewable energy for electricity generation systems—A review. Renewable & Sustainable Energy Reviews. 13, 1067–1073.

Bickerstaff, K., Lorenzoni I., Pidgeon, N.F., Poortinga, W., Simmons, P., 2008. Reframing nuclear power in the UK energy debate: nuclear power, climate change mitigation and radioactive waste, Public Understanding of Science, 17(2), pages 145–169.

Blok, K., 2007. Introduction to energy analysis. Techne Press, Amsterdam, The Netherlands.

Bookchin, M., 1990. Remaking Society: Pathways to a Green Future. South End Pr.

Bovend'Eert, P.P.T., Kummeling, H.R.B.M., 2010. Het Nederlandse parlement, Kluwer, Nijmegen, the Netherlands.

Bradbury, J., Greenberg, S., Wade, S., 2011. Communicating the risks of CCS, available online at: http://decarboni.se/sites/default/files/publications/21027/communicating-risks-ccs.pdf.

Bradbury, J., Ray, I., Peterson, T., Wade, S., Wong-Parodi, G., Feldpausch, A., 2009. The Role of Social Factors in Shaping Public Perceptions of CCS: Results of Multi-State Focus Group Interviews in the U.S, Energy Procedia 1, pages 4665–4672.

Broek, M. van den, Faaij, A., Turkenburg, W., 2008. Planning for an electricity sector with carbon capture and storage. International Journal of Greenhouse Gas Control, 2, 105–129.

Brunsting, S., Best-Waldhober, M. de, Feenstra, C.F.J., Mikunda, T., 2011a. Stakeholder participation practices and onshore CCS: Lessons from the Dutch CCS case Barendrecht, Energy Procedia 4, pages 6376–6383.

Brunsting, S., Upham, P., Dütschke, E., Best-Waldhober, M. de, Oltra, C., Desbarats, J., Riesch, H., Reiner, D. 2011b. Communicating CCS: Applying communications theory to public perceptions of carbon capture and storage, International Journal of Greenhouse Gas Control 5, pages 1651–1662.

Bueren, E.M. Van, Klijn, E., Koppenjan, J.F.M., 2003. Dealing with Wicked Problems in Networks : Analyzing an Environmental Debate from a Network Perspective Journal of Public Administration Research and Theory, Vol. 13, no. 2, pp. 193–212.

Burningham, K., 2000. Using the Language of NIMBY: A topic for research, not an activity for researchers, The International Journal of Local Environment, Vol. 5, No. 1, pages 55–67.

Burstein, P., 2003. The Impact of Public Opinion on Public Policy: A Review and an Agenda, Political Research Quarterly, Vol. 56, No. 1, March 2003, pages 29-40.

CATO, 2009. Catching carbon to clear the skies, experiences and highlights of the Dutch R&D programme on CCS, Visser, E. de, Vos, R. de, Hendriks, C. (Eds.), Utrecht, Netherlands.

CATO, 2011. Website: www.CO_2-cato.org, last accessed 1 December 2011.

CATO, 2014. Linking the Chain CCS - Integrated CATO-2 knowledge prepares for the next step in CO_2 Capture & Storage, Vos, R. de, (Ed.), Utrecht, the Netherlands.

CDA, 2006. Vertrouwen in Nederland - Vertrouwen in elkaar, Verkiezingsprogramma 2006-2011, Christen Democratisch Appèl (CDA).

CDA, 2010. Slagvaardig en samen, Verkiezingsprogramma 2010-2015, Christen Democratisch Appèl (CDA).

CDA, 2012. Iedereen, Verkiezingsprogramma 2012-2017, Christen Democratisch Appèl (CDA).

Chen, S., Chaiken, S., 1999. The Heuristic-Systematic Model in Its Broader Context. Dual-process Theories in Social Psychology, Chaiken, S., Trope, Y. (Eds), Guilford Press, New York, US, pages 73-96.

CO2CRC, 2014. Illustration 'CCS facilities', URL http://www.co2crc.com.au/images/imagelibrary/gen_diag/ccs_facilities_media.jpg (accessed 19.9.14)

Coates, J.J,1980. A Guidebook for Technology Assessment and Impact Analysis. In: A. L. Porter, F. A. Rossini, S. R. Carpenter, and A. T. Roper, eds., North Holland, New York/Oxford, 1980

Cobb, M.D., Kuklinski, J.H., 1997. Changing Minds : Political Arguments and Political Persuasion, American Journal of Political Science, vol. 41, no. 1, pp. 88–121.

Coninck, H.de, Flach, T., Curnow P., Richardson, P., Anderson, J., Shackley, S., Sigurthorsson, G., Reiner D., 2009. The acceptability of CO_2 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, pages 333-343.

Coninck, H. de, 2010. Advocacy for carbon capture and storage could arouse distrust, Nature 463, page 293.

CORDIS, 2010. Community Research and Development Information Service of the EU, available online at: http://www.cordis.europa.eu, visited October 2010.

Corry, O., Reiner, D., 2011. Carbon Capture and Storage Technologies and the Environmental Movement, CSIRO, Australia.

Corsten, M., Ramírez, A., Shen, L., Koornneef, J., Faaij, A., 2013. Environmental impact assessment of CCS chains – Lessons learned and limitations from LCA literature. International Journal of Greenhouse Gas Control 13, 59–71.

CPB, 2010. Netherlands Bureau for Economic Policy Analysis (CPB) and Netherlands Environmental Assessment Agency (PBL), Keuzes in kaart 2011-2015, Effecten van negen verkiezingprogramma's op economie en milieu, The Hague, the Netherlands.

CPB, 2012. Netherlands Bureau for Economic Policy Analysis (CPB) and Netherlands Environmental Assessment Agency (PBL), Effecten op economie en milieu, Keuzes in Kaart 2013-2017, Een analyse van tien verkiezingsprogramma's, The Hague, the Netherlands.

CSLF, 2011. Technology Roadmap 2011, Carbon Sequestration Leadership Forum (CSLF), online available at: http://www.cslforum.org/publications/documents/CSLF_Technology_Roadmap_2011.pdf.

CU, 2002. Durf te kiezen voor normen, verkiezingsprogramma 2002 - 2006, ChristenUnie (CU).

CU, 2010. Vooruitzien, Christelijk-sociaal perspectief, Verkiezingsprogramma ChristenUnie, 2010-2014, ChristenUnie (CU).

CU, 2012. Voor de verandering : 7 christelijk-sociale hervormingen, verkiezingsprogramma 2013-2017, ChristenUnie (CU).

Curry, T.E., Ansolabehere, S., Herzog, H., 2007. A Survey of Public Attitudes towards Climate Change and Climate Change Mitigation Technologies in the United States: Analyses of 2006 Results, Laboratory for Energy and the Environment, available online at: http://sequestration.mit.edu/pdf/LFEE_2007_01_WP.pdf.

D66, 2002. Toekomst in eigen hand, verkiezingsprogramma Democraten 66 - 2002-2006, Democraten 66 (D66).

D66, 2010. We willen het anders, verkiezingsprogramma Democraten 66 - 2010-2014, Democraten 66 (D66).

Dahowski, R.T., Li, X., Davidson, C.L., Wei, N., Dooley, J.J., Gentile, R.H., 2009. A preliminary cost curve assessment of carbon dioxide capture and storage potential in China. Energy Procedia 1, 2849–2856.

Davison, J., 2009. Electricity systems with near-zero emissions of CO_2 based on wind energy and coal gasification with CCS and hydrogen storage, International Journal of Greenhouse Gas Control, 3, pages 683–692.

De Coninck, H., Flach, T., Curnow, P., Richardson, P., Anderson, J., Shackley, S., Sigurthorsson, G., Reiner, D., 2009. The acceptability of

CO_2 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, 333–343.

Dear, M., 1992. Understanding and Overcoming the NIMBY Syndrome. Journal of the American Planning Association. 58, 288–300.

Deschouwer, K., Hooghe, M., 2011. Politiek: een inleiding in de politieke wetenschappen. Boom Lemma uitgevers, Den Haag.

Devine-Wright, P., 2005. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy, Wind Energy, 8, pages 125–139.

Devos, C., Lannoo, S., Ossenblok, K., Rommel, J., Liefferinge, H. van, 2012. Besluiten tot beleid, Inleiding in de politieke besluitvormingstheorie, Academia Press, Gent, Belgium.

DOE and NETL, 2010. Carbon Dioxide Capture and Storage RD&D Roadmap, Department Of Energy US (DOE) and National Energy Technology Laboratory (NETL).

Dryzek, J.S., Schlosberg, D. (Eds.), 2005. Debating the Earth: The Environmental Politics Reader, 2 edition. ed. Oxford University Press, Oxford ; New York.

Eagly, A.H., Wood, W., Chaiken, S., 1978. Causal inferences about communicators and their effect on opinion change, Journal of Personality and Social Psychology, 36(4), pages 424–435.

Eames, M., McDowall, W., Hodson, M., & Marvin, S, 2006. Negotiating contested visions and place-specific expectations of the hydrogen economy. Technology Analysis & Strategic Management, 18(3/4), 361–374.

EC, 2006. Community framework for state aid for research and development and Innovation, European Commission, 2006/C 323/01, Brussels, Belgium

EC, 2007. An energy policy for Europe, Com 1 Final, Communication from the Commission to the European Council and the European Parliament, Bussels, Belgium.

ECN, 2007. Verkenning potentieel en kosten van klimaat en energiemaatregelen voor Schoon en Zuinig, ECN-E–07-032, Menkveld, M., Wijngaart, R.A. van den, (Eds.), available online at: http://www.ecn.nl/pub/www/library/report/2007/e07032.pdf, Energieonderzoek Centrum Nederland (ECN), Petten, the Netherlands,

Economic Affairs, 1992. Tweede Structuurschema Elektriciteitsvoorziening Deel 1, 22 606 nr. 1, 22 May 1992.

Economic Affairs, 2006. Brief van de Minister van Economische Zaken, 30 000 nr. 44, 4 December 2006.

Economic Affairs, 2007. Brief van de minister van Economische Zaken, 30 000 nr. 45, 16 April 2007.

Economic Affairs, 2008. Brief van de ministers van Economische Zaken en van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Energie rapport 2008, 31 510 Nr. 1, 18 Juni 2008.

Economic Affairs, 2009a. Brief van de ministers van Economische Zaken en van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 31 209 nr. 103, 18 November 2009.

Economic Affairs, 2009b. Brief van de ministers van Economische Zaken en van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 31 510 nr. 33, 6 February 2009.

Economic affairs, 2009c. Brief van de minister van Economische Zaken, 31 510 nr. 37, 2 September 2009.

Economic Affairs, 2010a. Brief van de minister van Economische Zaken, Landbouw en Innovatie, 28 982 nr. 113, 4 November 2010.

Economic Affairs, 2010b. Brief van de minister van Economische Zaken en van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 28 982 nr. 104, 12 April 2010.

Economic Affairs, 2013. Brief van de minster van Economische zaken over het Energieakkoord voor Duurzame Groei, 30 196, nr. 202, 12 September 2013.

Egmond, S. van, Brouwer, J.H., Heimeriks, G.J., Hekkert, M.P., 2012. Overview and analysis of the Dutch CCS program as a knowledge network, International Journal of Greenhouse Gas Control, 11, pages S1–S9.

Egmond, S. van, Hekkert, M.P., 2012. Argument map for carbon capture and storage, International Journal of Greenhouse Gas Control, 11S, pages S148–S159.

Egmond, S. van, Hekkert, M.P., 2015. An Analysis of a prominent carbon storage project failure - The role of the national government as initiator and decision maker in the Barendrecht case, International Journal of Greenhouse Gas Control, in press.

Electoral Council, 2014. Database with results of elections in the Netherlands, online available at: http://www.verkiezingsuitslagen.nl, last accessed 28 July 2014.

Ende, J. van den, Mulder, K., Knot, M., Moors, E., Vergragt, P., 1998. Traditional and Modern Technology Assessment: Toward a Toolkit. Technological Forecasting and Social Change, 58, 5–21.

Environmental Affairs, 1991. Nota Klimaatverandering, 22 232 nr. 2, 4 September 1991.

Environmental Affairs, 2006. Brief van de staatssecretaris van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer over Kerncentrale Borssele, 30 000, nr. 18, 10 January 2006.

Environmental Affairs, 2007. Werkprogramma Schoon en Zuining - Nieuwe energie voor het klimaat, 31 209 nr.1., 24 September 2007.

EU, 2009. EU Official Journal Publication: 9/2009, 10694-2009, The Publications Office of the European Union (EU), Brussels, Belgium.

EU, 2011. Communication from the commission to the European Parliament, A Roadmap for moving to a competitive low carbon economy in 2050, 8 March 2011 COM(2011) 112 final, European Union (EU), Brussels, Belgium.

EU, 2014. A policy framework for climate and energy in the period from 2020 to 2030 - communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, European Union (EU), Brussels, Belgium.

Farla, J.C.M., Hendriks, C.A., Blok, K., 1995. Carbon dioxide recovery from industrial processes. Climate Change.

FD, 2007. Shell Nederland verhoogt investeringen, Het Financieele Dagblad (FD), 8 May 2007.

Feenstra, C.F.J., Mikunda, T., Brunsting, S., 2010. What happened in Barendrecht ? – Case study on the planned onshore carbon dioxide storage in Barendrecht, the Netherlands, ECN Report, ECN-E-10-057, Energieonderzoek Centrum Nederland (ECN), Petten, the Netherlands.

Fischedick, M., Pietzner, K., Supersberger, N., Esken, A., Kuckshinrichs, W., Zapp, P., Linßen, J., Schumann, D., Radgen, P., Cremer, C., Gruber, E., Schnepf, N., Roser, A., Idrissova, F., 2009. Stakeholder acceptance of carbon capture and storage in Germany, Energy Procedia, 1, 4783–4787.

Fischhoff, B., 1995. Risk perception and commication unplugged: twenty years of process. Risk Analalysis. 15, 137–145.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., Combs, B., 1978. How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy Sciences. 9, 127–152.

Gasalarm, 2011. Press release: 2x zoveel bezwaren tegen Gasopslag Bergermeer als tegen CO_2 in Barendrecht.

GCCSI, 2011a. The global status of CCS: 2010, Global CCS Institute (GCCSI), Canberra, Australia.

GCCSI, 2011b. Economic assessment of carbon capture and storage technologies: 2011 update, Global CCS Institute (GCCSI), Canberra, Australia.

GCCSI, 2011c. The costs of CCS and other low-carbon technologies, Global CCS Institute (GCCSI), Canberra, Australia.

GCCSI, 2012. The global status of CCS 2012, Global CCS Institute (GCCSI), Canberra, Australia.

GCCSI, 2014a. Status of CCS Project Database - Data, Global CCS Institute (GCCSI), 7 October 2014, Canberra, Australia.

GCCSI, 2014b. The global Status of CCS update February 2014, Global CCS Institute (GCCSI), Canberra, Australia.

Green4sure, 2007. Het groene energieplan, Rooijers, F.J., Boon, B.H., Faber, J. et al. (Eds.), CE Delft, Delft, the Netherlands.

Greenpeace, 2008a. Fabeltjescourant over de afvang van CO_2, online available at: http://www.greenpeace.nl/reports/fabeltjescourant-over-de-afvan/, Greenpeace Nederland, Amsterdam, the Netherlands.

Greenpeace, 2008b. False hope - Why carbon capture and storage won't save the climate, Kuper, J. (Ed.), Greenpeace International, Amsterdam, the Netherlands.

Greenpeace, 2012. Energy [r]evolution - a sustainable energy outlook, Greenpeace International, Amsterdam, the Netherlands.

Groenenberg, H., de Coninck, H., 2008. Effective EU and Member State policies for stimulating CCS. International Journal of Greenhouse Gas Control, 2, 653–664.

Groot, J.I.M. de, Steg, L. 2010. Morality and Nuclear Energy: Perceptions of Risks and Benefits, Personal Norms, and Willingness to Take Action Related to Nuclear Energy, Risk Analysis Journal, 30(9), pages 1363–1373.

Gunther, R., Diamond, L., 2003. Species of Political Parties: A New Typology. Party Politics. 9, 167–199.

Gupta, N., Fischer, a. R.H., Frewer, L.J., 2012. Socio-psychological determinants of public acceptance of technologies: A review. Public Understanding of Science, 21, 782–795.

GWEC, 2013. Global wind report - annual market update 2013, Global Wind Energy Council (GWEC), Brussels, Belgium.

Ha-Duong, M., Nadaï, A., Campos, A.S., 2009. A survey on the public perception of CCS in France, International Journal of Greenhouse Gas Control, 3, pages 633–640.

Hammond, J., Shackley, S., 2010. Towards a public communication and engagement strategy for carbon dioxide capture and storage projects in Scotland: A Review of research findings, CCS project experiences, tools, resources and best practices, working paper: SCCS 2010-08.

Hardin, G., 1968. The tragedy of the commons. The population problem has no technical solution; it requires a fundamental extension in morality. Science (80-.). 162, 1243–1248.

Haskoning, 2011. Milieueffectrapportage CCS Maasvlakte (ROAD project), Deelrapport Afvang, Royal Haskoning, Nijmegen, the Netherlands.

Hendriks, C., Koornneef, J., 2014. CCS Implementation Plan, report with accompanying website, available online at: http://ccs-roadmap.ecofys.com, Ecofys, Utrecht, the Netherlands.

Hendriks, C.A., Blok, K., 1989. Utilization Possibilities and Costs of Recovery and Storage of Carbon Dioxide, Department of Science, Technology and Society, University of Utrecht, The Netherlands.

Hill, W.E., 1915. My Wife and My Mother-in-Law, Puck magazine, page 11, 6 November. 1915.

Hoogwijk, M., de Vries, B., Turkenburg, W., 2004. Assessment of the global and regional geographical, technical and economic potential of onshore wind energy. Energy Economics. 26, 889–919.

Huijts, N.M.A., Midden, C.J.H., Meijnders, A.L., 2007. Social acceptance of carbon dioxide storage, Energy Policy, 35, pages 2780–2789.

Huijts, N.M.A., Molin, E.J.E., Steg, L., 2012. Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. Renewable & Sustainable Energy Reviews. 16, 525–531.

IEA, 2010. Energy Technology Perspectives 2010, Scenarios and Strategies to 2050, Organisation for Economic Co-operation and Development (OECD)/ International Energy Agency (IEA), Paris, France.

IEA, 2013a. Redrawing the energy-climate map, World Energy Outlook Special Report, International Energy Agency (IEA), Paris, France.

IEA, 2013b. Technology Roadmap Carbon capture and storage edition 2013, International Energy Agency (IEA), Paris, France.

IEA, 2014a. Technology Roadmap - Solar Photovoltaic Energy. International Energy Agency (IEA), Paris, France.

IEA, 2014b. Energy Technology Perspectives 2014. International Energy Agency (IEA), Paris, France.

IEAGHG, 2002. Opportunities for early application of CO_2 sequestration technology, International Energy Agency Greenhouse Gas R&D Programme (IEAGHG), Cheltenham, United Kingdom.

IEAGHG, 2006. Near zero emission technology for CO_2 capture from power plants, 2006/13, International Energy Agency Greenhouse Gas R&D Programme (IEAGHG), Cheltenham, United Kingdom

IEAGHG, 2009. Safety in Carbon Dioxide capture and storage, 2009, International Energy Agency Greenhouse Gas R&D Programme (IEAGHG), Cheltenham, United Kingdom.

IEAGHG, 2010. 1st Meeting of the Social Research Network, 2010/9, June, International Energy Agency Greenhouse Gas R&D Programme (IEAGHG), Cheltenham, United Kingdom.

IPCC, 2005. Special report on carbon dioxide capture and storage, Metz, B., Davidson, O., Coninck, H. de, Loos, M., Meyer, L. (Eds.), Prepared by Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York, US.

IPCC, 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, New York, US.

Itaoka, K., Saito, A., Paukovic, M., Best-waldhober, M. De, Dowd, A., Jeanneret, T., Ashworth, P., James, M., 2012. Understanding how individuals perceive carbon dioxide, CSIRO, Australia.

Jobert, A., Laborgne, P., Mimler, S., 2007. Local acceptance of wind energy: Factors of success identified in French and German case studies. Energy Policy 35, 2751–2760.

Johnsson, F., Reiner, D., Itaoka, K., Herzog, H., 2010. Stakeholder attitudes on Carbon Capture and Storage—An international comparison. International Journal of Greenhouse Gas Control, 4, 410–418.

Jong, K.P. de., 2010. Personal communication during 5th Dutch CCS conference, 25 June 2010, Utrecht University, Utrecht, the Netherlands.

Kahan, D.M., 2010. Fixing the communications failure, Nature, 463, pages 296–297.

Kahan, D.M., Peters E., Wittlin, M., Slovic, P., Larrimore Ouellette, L., Braman, D., Mandel, G., 2012. The polarizing impact of science literacy and numeracy on perceived climate change risks, Nature Climate Change, 2, pages 732–735.

Kalshoven, F., 2010. Personal communication with F. Kalshoven, director Argument Factory, 23 April 2010.

Kieskompas, 2014. Dutch Voter Advice Application, Available online at: http://www.tweedekamer2010.kieskompas.nl/help, last assessed 27 October 2014.

Kliest, A., 2010. Beeldvorming over CO_2 afvang en opslag, MSc Thesis, Faculty of Geosciences, Utrecht University, Utrecht, the Netherlands.

Koornneef, J., Keulen, T. van, T., Faaij A.P.C., Turkenburg W.C., 2008. Life cycle assessment of a pulverised coal power plant with post-combustion capture, transport and storage of CO_2, International Journal of Greenhouse Gas Control, 2, pages 448-467.

Krewitt, W., 2002. External costs of energy—do the answers match the questions? Energy Policy 30, 839–848.

Krütli, P., Flüeler, T., Stauffacher, M., Wiek, A., Scholz, R.W., 2010. Technical safety vs. public involvement? A case study on the unrealized project for the disposal of nuclear waste at Wellenberg (Switzerland). Journal of Integrative Environmental Sciences, 7, 229–244.

Kuijper, M., 2011. Public acceptance challenges for onshore CO_2 storage in Barendrecht, Energy Procedia, 4, pages 6226–6233.

Kunze, C., Spliethoff, H., 2012. Assessment of Oxy-Fuel, Pre- and Post-Combustion-Based Carbon Capture for Future IGCC Plants, Applied Energy, 94(0), pages 109-116.

L'Orange Seigo, S., Dohle, S., Siegrist, M., 2014. Public perception of carbon capture and storage (CCS): A review, Renewable & Sustainable Energy Reviews, 38, pages 848–863.

Layton, D.F., 2000. Random Coefficient Models for Stated Preference Surveys, Journal of Environmental Economics and Management, 40(1), pages 21–36.

Leiden University, 2013. Public information website of Parliamentary Documentation Centre, Leiden University, available online at: http://www.parlement.com, last accessed 4 December 2013.

Lexis Nexis, 2014. Database of Dutch newspapers, online available at: http://academic.lexisnexis.nl/.

Lomborg, B., 2001. The Skeptical Environment: Measuring the Real State of the World. Cambridge University Press.

Ludig S., Haller M., Schmid E., Bauer N., 2011. Fluctuating renewables in a long-term climate change mitigation strategy, Energy, 36, pages 6674-6685.

Lupion, M., Herzog, H.J., 2013. Lessons learnt in attempting to secure CCS projects in Europe, International Journal of Greenhouse Gas Control 19, pages 19–25.

Markusson, N., Ishii, A., Stephens, J.C., 2011. The social and political complexities of learning in carbon capture and storage demonstration projects, Global Environmental Change 21, pages 293–302.

Markusson, N., Kern, F., Watson, J., Arapostathis, S., Chalmers, H., Ghaleigh, N., Heptonstall, P., Pearson, P., Rossati, D., Russell, S., 2012a. A socio-technical framework for assessing the viability of carbon capture and storage technology, Technological Forecasting and Social Change, 79, pages 903–918.

Markusson, N., Shackley, S., Evar, B., 2012b. The Social Dynamics of Carbon Capture and Storage: Understanding CCS Representations, Governance and Innovation, Routledge, Abingdon, United Kingdom.

Meadowcroft, J., Langhelle, O. (Eds.), 2011. Caching the Carbon: The Politics and Policy of Carbon Capture and Storage, Edward Elgar, Cheltenham, United Kingdom.

Meadows, D.H., Meadows, D.L., Randers, J., Behrens, W.W., 1972. The Limits to Growth, Chelsea. Universe Books.

Meerman J.C., Ramirez A., Turkenburg W.C., Faaij A.P.C., 2011. Performance of simulated flexible integrated gasification polygeneration facilities. Part A: A technical-energetic assessment, Renewable and Sustainable Energy Reviews 2011, 15, pages 2563-87.

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C.B., Frieler, K., Knutti, R., Frame, D.J., Allen, M.R., 2009. Greenhouse-gas emission targets for limiting global warming to 2 °C, Nature, 458, pages 1158-1162.

Meyerowitz, B.E., Chaiken, S., 1987. The Effect of Message Framing on Breast Self-Examination Attitudes, Intentions, and Behavior, Journal of Personality and Social Psychology, 52(3), pages 500–510.

Michael, J., Choptiany, H., Pelot, R., Sherren, K., 2014. An Interdisciplinary Perspective on Carbon Capture and Storage Assessment Methods, Journal of Industrial Ecology, Volume 18, Issue 3, pages 445–458, June 2014

Mors, E. ter, Weenig, M.W.H., Ellemers, N., Daamen, D.D L., 2010, Effective communication about complex environmental issues: Perceived quality of information about carbon dioxide capture and storage (CCS) depends on stakeholder collaboration, Journal of Environmental Psychology, 30, pages 347–357.

Ter Mors, E., Terwel, B.W., Daamen, D.D.L., Reiner, D.M. et al. 2013. A comparison of techniques used to collect informed public opinions about CCS: Opinion quality after focus group discussions versus information-choice questionnaires. International Journal of Greenhouse Gas Control, 18, pages 256-263.

Nackenhorst, K., Olsthoorn, M., Warmenhoven, H., Soest, J.P. van, 2009. CO_2 - afvang en opslag: Vijgenblad, noodzakelijk kwaad of wereldkans? - Eindrapport EDN CCS-Dialoog -, Stichting Energie Dialoog Nederland (EDN), Rotterdam, the Netherlands.

Naess, A., 1973. The shallow and the deep, long-range ecology movement - A summary. Inquiry. 16 (1-4):95 – 100 (1973)

Notten, P.W. van., Rotmans, J., van Asselt, M.B.., Rothman, D.S., 2003. An updated scenario typology. Futures 35, 423–443.

NCEA, 2009. Toetsingsadvies over het milieueffectrapport, Ondergrondse opslag van CO_2 in Barendrecht, 2047-172, Netherlands Commission for Environmental Assessment (NCEA), Utrecht, the Netherlands.

NRC, 2008. National daily newspaper, Zonder CO_2-opslag kunnen we het schudden, NRC, 4 July 2008, Rotterdam, the Netherlands.

NRC, 2009a. National daily newspaper, Ministers trotseren boze en bange burgers, NRC, 2 December 2009, Rotterdam, the Netherlands.

NRC, 2009b. National daily newspaper, Opslag CO_2 in leeg gasveld is niet veilig, Geen experimenten in woonwijk, Jong, K.P. de, NRC, 5 March 2009, Rotterdam, the Netherlands.

NRC, 2009c. National daily newspaper, Ook CCS noodzakelijk om klimaatverandering tegen te gaan, Lubbers, R.F.M. et al., NRC, 2 September 2009, Rotterdam, the Netherlands.

NRC, 2011. National daily newspaper, Onterechte angst voor opslag CO_2, CO_2-lek in Canada zorgt voor onrust in Nederland, NRC, 11 February 2011, Rotterdam, the Netherlands.

NVivo, 2012. Computer Software, version 10, QSR International ltd, London, retrieved from: http://www.qsrinternational.com/

Nylund, K.L., Asparouhov T., Muthén B.O., 2007. Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: a Monte Carlo Simulation Study, Structural Equation Modeling: A Multidisciplinary Journal, 14(4), pages 535–569.

OCAP, 2007. OCAP: CO_2 horticultural greenhouse - Factsheet, (year estimated), Schiedam, the Netherlands.

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, pages 698–706.

Oltra, C., Upham, P., Riesch, H., Boso, À., Brunsting, S., Dütschke, E., Lis, A., 2012. Public responses to CO_2 storage sites: Lessons from five European cases, Energy & Environmental Science, 23.

Orr, F.M., 2009. Onshore geologic storage of CO_2. Science 325, 1656–1658.

Otjes, S., Louwerse, T., 2015. Populists in Parliament: Comparing Left-Wing and Right-Wing Populism in the Netherlands. Political Studies, Volume 63, Issue 1, pages 60–79, March 2015

Parliament, 2004. Onderzoek naar infrastructuurprojecten, Reconstructie Betuweroute: de besluitvorming uitvergroot 29 283 Nr. 7, 15 December 2004.

Parliament, 2005a. Verslag van een algemeen overleg, Waddenzeebeleid, 29 684 Nr. 30, 10 February 2005.

Parliament, 2005b. Verslag van een algemeen overleg, Voorzienings- en leveringszekerheid energie, 29 023 Nr. 18, 12 December 2005.

Parliament, 2006. Verslag van een algemeen overleg, Raad voor Vervoer, Telecommunicatie en Energie, 22 112 Nr. 102, 7 June 2006.

Parliament, 2007a. Verslag algemeen overleg 'Evaluatienota Klimaatbeleid', Tweede Kamer, vergaderjaar 2006–2007, 28 240, nr. 86.

Parliament, 2007b. Verslag van een Nota overleg, Schoon en Zuinig,31 209 Nr. 7, 29 October 2007.

Parliament, 2008a. Verslag van een notaoverleg mbt het Europese Energie- en Klimaatpakket, 31 209 nr. 25, 27 February 2008.

Parliament, 2008b. Schriftelijke vragen van het lid Vendrik (GroenLinks) aan de ministers van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer en van Economische Zaken over CO_2-opslag in Barendrecht, 2080907720, 15 December 2008.

Parliament, 2008c. Verslag van een wetgevingsoverleg, Energierapport 2008, 31 510 Nr. 6, October 2008.

Parliament, 2008d. Verslag van een algemeen overleg, Milieuraad,21 501-08 Nr. 291, 9 October 2008.

Parliament, 2009a. Verslag van een Nota overleg, Duurzame ontwikkeling en beleid, 30 196 Nr. 63, 15 June 2009.

Parliament, 2009b. Mondelinge vragenuur, vragen van het lid Jansen (SP) aan de minister van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer over dat de minister het CO_2-proef- project in Barendrecht wil doorzetten ondanks de bezwaren van de gemeente en de bewoners, 61-4886 t/m 61-4888, 10 March 2009.

Parliament, 2009c. Indiening Crisis- en herstelwet, 32 127 nr. 2, 29 September 2009.

Parliament, 2009d. Verslag van de behandeling van het wetsvoorstel Regels met betrekking tot versnelde ontwikkeling en verwezenlijking van ruimtelijke en infrastructurele projecten (Crisis- en herstelwet 32 127), 24-2140 t/m 24-2204, 12 November 2009.

Parliament, 2009e. Verslag van een algemeen overleg van de vaste commissie voor Economische Zaken met minister Van der Hoeven van Economische Zaken, 31 239 nr. 72, 3 September 2009.

Parliament, 2009f. Verslag van een algemeen overleg, Stimulering duurzame energieproductie, 31 239 Nr. 90, 2 December 2009.

Parliament, 2009g. Verslag van een algemeen overleg, 31 209 nr. 111, 19 November 2009.

Parliament, 2010a. Stemmingen over moties, ingediend bij de behandeling van het verslag van een algemeen overleg met de minister van Economische Zaken over energie en gasopslag (31 209, nr. 111), 46-4380 t/m 46-4381, 26 January 2010.

Parliament, 2010b. Verslag van een wetgevingsoverleg, Vaststelling van de begrotingsstaten van het Ministerie van Economische Zaken, Landbouw en Innovatie (XIII) voor het jaar 2011, 32 500 Nr. 157, 6 December 2010.

Parliament, 2010c. Verslag van een algemeen overleg met de minister van Economische Zaken over energie en gasopslag, 41-3960 t/m 41-3975, 13 January 2010.

Parliament, 2010d. Brief van Minister president Balkende aan H.M. de Koningin, 32 324 nr. 1, 20 February 2010.

Parliament, 2010e. Stemming over aangehouden motie (28 982, nr. 105), 86-7287, 20 May 2010.

Parliament, 2010f. Verslag voorzetting van het debat over het bericht 'CO_2-bom onder Barendrecht', 79-6691 t/m 79-6701, 21 April 2010.

Parliament, 2010g. Verslag van het debat over 'Verkeerde informatie IPCC-rapport', 48-45538 t/m 48-4559, 8 January 2010

Parliament, 2010h. Behandeling van 'Verslag van een algemeen overleg, Schoon en zuinig, 31 209 Nr. 111, 19 November 2009', 13 January 2010.

Parliament, 2010i. Verslag van het debat over het bericht ”CO_2-bom onder Barendrecht”, 78-6626 t/m 78-6652, 20 April 2010.

Parliament, 2011. Algemene beraadslaging over het wetsvoorstel Wijziging van de Mijnbouwwet (32343), nr 42 item 9, 20 January 2011

Paukovic, M., Brunsting, S., Best-Waldhober, M. de, 2011, The Dutch general public's opinion on CCS and energy transition: Development in awareness, knowledge, beliefs and opinions related to information and media coverage, ECN, Amsterdam, the Netherlands.

Pehnt, M., 2006. Dynamic life cycle assessment (LCA) of renewable energy technologies. Renewable Energy 31, 55–71.

Petities.nl, 2013. Website to facilitate public petitions, http://geenCO2.petities.nl, last accessed 4-12-2013.

Petty, R.E., Wegener, D.T., 1999. The Elaboration Likelihood Model: Current Status and Controversies. Dual-process Theories in Social Psychology, Chaiken, S., Trope, Y., (Eds.), Guilford Press, New York, US, pages 41-72.

Platform Nieuw Gas, 2007. Werkgroep CO_2 - opslag/Schoon fossiel, Beleidsrapportage Schoon Fossiel, Utrecht, the Netherlands.

Pollak, M., Phillips, S.J., Vajjhala, S., 2011. Carbon capture and storage policy in the United States: A new coalition endeavors to change existing policy. Global Environmental Change 21, 313–323.

Poole, M.S., Ven, A.H. van de, Dooley, K., Holmes, M.E., 2000. Organizational Change and Innovation Processes, Theories and Methods for Research, Oxford University, New York, US.

PTRC, 2011. IEAGHG weyburn-midale CO_2 Monitoring &Storage project - Response to a soil Gas study Performed by Petro-find geochem Ltd, Petroleum Technology Research Centre (PTRC), January 2011, Regina, Canada.

PvdD, 2010. Recepten voor mededogen en duurzaamheid, verkiezingsprogramma partij voor de dieren, tweede kamerverkiezingen 2010.

Rand, A., 1975. Atlas Shrugged. Dutton, New York.

Rathenau Instituut, 2012. Overal robots, Automatisering van de liefde tot de dood. Lemma uitgevers, Den Haag, The Netherlands.

RCI, 2007a. The World Capital of CO_2-free energy, Rotterdam Climate Initiative (RCI), June 2007, Rotterdam, the Netherlands.

RCI, 2007b. The route to large scale CO_2 Capture and Transport in the Rotterdam Harbour Industrial Complex, Juli 2007, Rotterdam Climate Initiative (RCI), Rotterdam, the Netherlands.

Reiner, D.M.,2008. A looming rhetorical gap: a survey of public communications activities for carbon dioxide capture and storage technologies, Electricity Policy Research Group Working Paper 0801, University of Cambridge, Cambridge, United Kingdom.

Rittel, H.W.J., Webber, M.M., 1973. Dilemmas in a general theory of planning. Policy Sciences, 4, 155–169.

RIVM, 2002. Verkiezingen 2002, Milieu & Natuur -Een beoordeling van de partijprogramma's van PvdA, D66, GroenLinks, ChristenUnie en SP, Rijksinstituut voor Volksgezondheid en Milieu (RIVM), Bilthoven, the Netherlands.

RIVM, 2003. Nuchter omgaan met risico's. Milieu- en Natuurplanbureau (MNP)/ RIVM, Bilthoven.

RIVM, 2013. Greenhouse gas emissions in the Netherlands 1990-2011, National Inventory Report 2013, National Institute Public Health and the Environment, Bilthoven, the Netherlands.

Sabatier, P.A., 1988. An advocacy coalition framework of policy change and the role of policy-oriented learning therein. Policy Sciences, 21, pages 129–168.

SaskPower, 2014. SaskPower launches world ’ s first commercial CCS process, News release, 2 october 2014, Regina, Saskatchewan, Canada.

Schot, J. 2003. The Contested Rise of a Modernist Technology Politics, in: Misa, T.J., Brey, P. and Feenberg, A., Modernity and Technology, Massachusetts Institute of Technology, Boston, MA.

Schot, J., Rip, A., 1997. The Past and Future of Constructive Technology Assessment. Technological Forecasting and Social Change, 54, 251–268.

Schumacher, E.F., 1973. Small Is Beautiful - Economics as if People Mattered. Aviable on line http://www.ditext.com/schumacher/small/small.html (accessed 4.4.15).

Schumacher, K., Sands, R.D., 2006. Innovative energy technologies and climate policy in Germany. Energy Policy 34, 3929–3941.

Scott, V., Gilfillan, S., Markusson, N., Chalmers, H., Haszeldine, R.S., 2013. Last chance for carbon capture and storage, Nature Climate Change 3, pages 105–111.

SenterNovem, 2008. Europese Aanbesteding – CO_2 opslag in de Bodem – Aanbestedingsleidraad Definitieve inschrijving, 22 May 2008.

SER, 2013. Energieakkoord voor duurzame groei. Sociaal-Economische Raad (SER), The Hague, the Netherlands.

SGP, 2010. Daad bij het woord, de SGP staat ervoor!, verkiezingsprogramma 2010-2014, Staatkundig Gereformeerde Partij (SGP).

Shackley, S., McLachlan, C., Gough, C., 2004. The public perception of carbon dioxide capture and storage in the UK: results from focus groups and a survey, Climate Policy, 4, pages 377–398.

Shackley, S., Reiner, D., Upham, P., Coninck, H. de, Sigurthorsson, G., Anderson, J., 2009. The acceptability of CO_2 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, pages 344–356.

Shackley, S., Waterman, H., Godfroij, P., Reiner, D., Anderson, J., Draxlbauer, K., Flach, T., 2007. Stakeholder perceptions of CO_2 capture and storage in Europe: Results from a survey, Energy Policy, 35, pages 5091–5108.

Sharp, J.D., Jaccard, M.K., Keith, D.W., 2009. Anticipating public attitudes toward underground CO_2 storage, International Journal of Greenhouse Gas Control, 3, pages 641–651.

Shell, 2008a. MER Ondergrondse opslag van CO_2 in Barendrecht, Deelrapport 1: Samenvattend hoofdrapport, Shell CO_2 Storage B.V., The Hague, the Netherlands.

Shell, 2008b. Press release ‘Shell urges government action on CO_2 emissions’, 7 April 2008, The Hague, the Netherlands.

Shell, 2013. New Lens scenarios - A shift in perspective for a world in transition. The Hague, the Netherlands.

Siegrist, M., Cvetkovich, G., 2000. Perception of Hazards: The Role of Social Trust and Knowledge. Risk Analalysis. 20, 713–720.

Simon, J.L., Kahn, H., 1984. The Resourceful Earth: A Response to Global 2000. Basil Blackwell, New York.

Singh, B., Strømman A.H., Hertwich E.G., 2011. Comparative life cycle environmental assessment of CCS technologies, International Journal of Greenhouse Gas Control, 5, pages 911-921.

Skowronski, J.J., Carlston, D.E., 1987. Social Judgment and Social Memory: The Role of Cue Diagnosticity in Negativity, Positivity, and Extremity Biases, Journal of Personality and Social Psychology, vol. 52, no. 4, pp. 689–699.

Slovic, P., Finucane, M.L., Peters, E., MacGregor, D.G., 2004. Risk as analysis and risk as feelings. Risk Analysis. 24.

Slovic, P., Finucane, M.L., Peters, E., MacGregor, D.G., 2007. The affect heuristic, European Journal of Operational Research, 177(3), pages 1333–1352.

Soest, J.P. van, 2014. De Twijfelbrigade. Maurits Groen, Haarlem.

Stern, D.I., Common, M.S., Barbier, E.B., 1996. Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development. World Development, 24, 1151–1160.

Swait, J., Louviere, J., 1993. The Role of the Scale Parameter in the Estimation and Comparison of Multinomial Logit Models, Journal of marketing research, 30(3), pages 305–314.

Terwel, B.W. 2008, Origins and consequences of public trust: Towards an understanding of public acceptance of carbon dioxide capture and storage, dissertation, Leiden University, the Netherlands.

Terwel, B.W., Harinck, F., Ellemers, N., Daamen, D.D.L., 2009. How organizational motives and communications affect public trust in organizations: The case of carbon dioxide capture and storage. Journal of Environmental Psychology, 29, 290–299.

Terwel, B.W., Harinck, F., Ellemers, N., Daamen, D.D.L., 2011, Going beyond the properties of CO_2 capture and storage (CCS) technology: How trust in stakeholders affects public acceptance of CCS, International Journal of Greenhouse Gas Control, 5, pages 181–188.

Terwel, B.W., Mors, E. ter, Daamen, D.D.L., 2012. It's not only about safety: Beliefs and attitudes of 811 local residents regarding a CCS project in Barendrecht, International Journal of Greenhouse Gas Control, 9, pages 41–51.

Thambimuthu, K., 2007. Mid-tem review report on CATO, Thambimuthu, K. (Ed), CATO, Utrecht, the Netherlands.

TNO, 2007. Options for CO_2 storage in the Netherlands - Time dependent storage capacity, hazard aspects, and regulations, 20 07-U-R0564/B, TNO Built Environment and Geosciences, Utrecht, the Netherlands.

Toke, D., Breukers, S., Wolsink, M., 2008. Wind power deployment outcomes: How can we account for the differences? Renewable & Sustainable Energy Reviews, 12, 1129–1147.

Tokushige, K., Akimoto, K., Tomoda, T., 2007. Public perceptions on the acceptance of geological storage of carbon dioxide and information influencing the acceptance, International Journal of Greenhouse Gas Control, 1, pages 101–112.

Transparent Cost Database, 2015. Open Energy Information http://en.openei.org/wiki/Transparent_Cost_Database (accessed 4.5.15).

UK, 2014. Next steps in CCS : Policy Scoping Document, Department of Energy & Climate Change, UK government.

UNESCO, 2010. UNESCO Science Report 2010, The Current Status of Science around the World, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France.

UNFCCC, 2009. Report of the Conference of the Parties on its fifteenth session, Copenhagen, Denmark, United Nations Framework Convention on Climate Change (UNFCCC), December 2009.

UNFCCC, 2010. Report of the Conference of the Parties on its sixteenth session, Cancun, Mexico, United Nations Framework Convention on Climate Change (UNFCCC), December 2010.

Upham, P., Roberts, T., 2011. Public perceptions of CCS in context: Results of NearCO2 focus groups in the UK, Belgium, the Netherlands, Germany, Spain and Poland. Energy Procedia 4, 6338–6344.

US, 2013. The presidents climate action plan, Obama-Biden Administration, Washington DC, US

Ven, A.H. van de, Polley, D.E., Garud, R., Venkataraman, S., 1999. The Innovation Journey, Oxford University Press, 1999. New York, US

Vermunt, J.K., Magidson, J., 2002. Latent class cluster analysis. Applied Latent Class Analysis, Hagenaars, J.A., McCutcheon, A.L. (Eds.), Cambridge University Press, New York, US, pages 89-106.

Vos, R. de , van Egmond, S., 2010. GHGT Times, Daily bulletin of the 10th Conference on Greenhouse Gas Control Technologies,19- 23 September 2010, Amsterdam RAI, Amsterdam, the Netherlands.

Vosbeek, M., Warmenhoven, H., 2007. Making large-scale Carbon Capture and Storage CCS in the Netherlands WORK, Ecofys, Utrecht, the Netherlands.

VVD and CDA, 2010. Vrijheid en verantwoordelijkheid, Regeerakkoord VVD-CDA, 30 September 2010.

Wall, M., Krouwel, A., Vitiello, T., 2012. Do voters follow the recommendations of voter advice application websites? A study of the effects of kieskompas.nl on its users' vote choices in the 2010 Dutch legislative elections, Party Polit.

Wallquist L., Visschers, V.H.M., Siegrist, M., 2010. Impact of Knowledge and Misconceptions on Benefit and Risk Perception of CCS, Environmental Science & Technology, 44(17), pages 6557–6562.

Wallquist, L., Seigo, S.L., Visschers, V.H.M., Siegrist, M., 2012a. Public acceptance of CCS system elements: A conjoint measurement, International Journal of Greenhouse Gas Control, 6, pages 77–83.

Wallquist, L., Visschers, V.H.M., Dohle, S., Siegrist, M., 2012b. The Role of Convictions and Trust for Public Protest Potential in the Case of Carbon Dioxide Capture and Storage (CCS), Human and Ecological Risk Assessment: An International Journal, 18, pages 919–932.

WEC, 2010. 2010 Survey of Energy Resources, World Energy Council (WEC), London, United Kingdom.

WEC, 2013. World Energy Scenarios: Composing energy futures to 2050, World Energy Council (WEC), London, United Kingdom.

Whitfield, S.C., Rosa, E.A., Dan, A., Dietz, T., 2009. The future of nuclear power: value orientations and risk perception. Risk Analysis. 29, 425–37.

Woerdman, E., 2013. Politiek en politicologie, Noordhoff uitgevers, Groningen, the Netherlands.

Wolsink, M., 2007. Wind power implementation: The nature of public attitudes: Equity and fairness instead of 'backyard motives', Renewable & Sustainable Energy Reviews 11, pages 1188–1207.

Wüstenhagen, R., Wolsink, M., Bürer, M.J., 2007. Social acceptance of renewable energy innovation: An introduction to the concept, Energy Policy 35(5), pages 2683–2691.

WWF, 2011. The energy report, 100% renewable energy by 2050, WWF/Ecofys/OMA, Gland, Switzerland.

Yang, H., Xu, Z., Fan, M., Gupta, R., Slimane, R.B., Bland, A.E., Wright, I., 2008. Progress in carbon dioxide separation and capture: A review. Journal of Environmental Sciences, 20, 14–27.

Zapp P., Schreiber A., Marx J., Haines M., Hake J., Gale J., 2012. Overall environmental impacts of CCS Technologies - A life cycle approach. International Journal of Greenhouse Gas Control 8, pages 12-21.

Zembla, 2010. Television Documentary, CO_2 Bomb under Barendrecht, Driehuis, K., VARA, 28 March 2010.

ZEP, 2012. Status Review -The formation, control and environmental fate of emissions from amine-based CO_2 capture plants, European Technology Platform for Zero Emission Fossil Fuel Power.

Zwaan, B. van der, Smekens, K., 2009. CO_2 Capture and Storage with Leakage in an Energy-Climate Model, Environmental Modelling & Assessment, 14, pages 135–148.

Dankwoord

Ook als je denkt dat het schrijven van een proefschrift een zware taak is, is deze toch nog zwaarder dan je dacht[1]. Het bewandelen van dit pad had ik nooit alleen gekund en ik ben velen, die geholpen hebben op deze tocht, grote dank verschuldigd. Sommigen liepen in verschillende periodes met me mee, anderen droegen mijn bagage of toonden de weg en weer anderen verzorgden de opgelopen blaren. Het zijn er te veel om op te noemen, maar ik wil enkelen toch bij naam noemen.

Als eerste wil ik Marko bedanken die het aandurfde dit ietwat ongewone promotietraject te begeleiden. Dat begon al met de vraagstelling. Ik werd gedreven vanuit persoonlijke nieuwsgierigheid en stelde een maatschappelijke vraag, in tegenstelling tot veel promotietrajecten waar de vraagstelling direct vanuit de wetenschap komt. Je moedigde me aan om te blijven zoeken zonder te ver af te wijken van de onderzoeksvraag.

Ook veel dank aan Jacco. Jij werd pas op eind betrokken bij mijn proefschrift. Je uiterst consciëntieuze aanpak dwong mij preciezer te werken en te verwoorden. Ook kon je me steeds opnieuw motiveren de haast eindeloze laatste loodjes te overwinnen.

Jan B: ik ben jou heel veel dank verschuldigd. Je gaf me ruimte en onvoorwaardelijke steun om mijn taken binnen CATO op mijn eigen manier in te vullen. Je zette de lijn van Erik Lysen voort, en stimuleerde dat er dat er juist binnen CATO kritische vragen over CCS gesteld moesten worden. Je moedigde me aan om mijn gedachten verder te onderzoeken en uiteindelijk uit te werken in dit proefschrift.

Jan H, met jouw voorliefde voor orde en regelmaat dwong je mij planmatig te werken. Dit zorgde ervoor dat ik concrete deadlines stelde en het hele project in behapbare stukken kon opdelen. Ook dank voor de vele gesprekken onder het genot van een broodje kroket.

Mirjam, Geertje en Marlies: jullie waren mijn steunpilaren op de universiteit. Heel erg bedankt voor al jullie ondersteuning, zoals het organiseren van bijeenkomsten, redigeren van teksten, het stellen van vragen, het overnemen van werkzaamheden tijdens mijn schrijfperiodes, etc etc. Samen hebben we de bijzondere situatie op de gang overleefd.

---

[1] vrij naar Judith Hertzberg.

Door de jaren heen heb ik met honderden mensen uit de CATO-gemeenschap mogen spreken over hun eigen fascinatie voor CCS en kon ik kennis nemen van hun werk. In het bijzonder wil ik Rob Arts, Gerdi Breembroek, Wim Brilman, Kevin Broecks, Ruud van den Brink, Dancker Daamen†, Stan Dessens, Eric van Dijk, Jan Wilco Dijkstra, Barend van Engelenburg, John Gale, Erwin Giling, Chris Gittins, Earl Goetheer, Chris Hendriks, Gaston Heimeriks, Daan Jansen, Krijn de Jong, Marc Kombrink, Joris Koornneef, Margriet Kuijper, Wim Mallon, Emma ter Mors, Filip Neele, Henk Pagnier, Andrea Ramirez, Andy Read, Frank Rijnsoever, Harry Schreurs, Paul van Slobbe, Chris Spiers, Mark Spruijt, Bart Terwel, Gerald Tory, Rolf de Vos, Ton Wildenborg en Karl-Heinz Wolf bedanken. En tevens ook de ruim 50 AIO's die het programma geteld heeft. Het was goed om onderdeel van deze club te zijn.

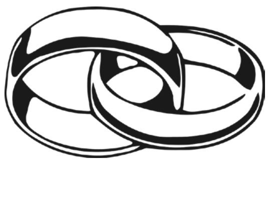
Mijn voorliefde voor energievraagstukken ontstond in mijn studietijd. Robert en Jasper dank voor de energieke, feitelijk correcte en vooral ook leuke gezellige discussies.

Ook wil ik de vrijwilligers van het gastenverblijf Slangenburg danken voor de goede zorgen en gesprekken. De rust en benedictijnse regelmaat stelden mij in staat om dit proefschrift daadwerkelijk te schrijven.

Philip en Lida, bedankt voor de eindeloze praktische ondersteuning door de kinderen op te vangen. En natuurlijk voor mijn vorming. De creativiteit en doorzettingsvermogen kwamen erg goed van pas. Karin, bedankt voor de introductie in de maatschappelijke zaak in Twente. Marjolein, jij hebt me er doorheen gesleept toen ik het helemaal niet meer zag zitten, zowel door enorme ondersteuning bij het schrijfproces, als door een ander kijk te geven van het wetenschapsbedrijf.

Tenslotte wil ik Tom, Roos en Cassandra danken. Jullie steunden me door dik en dun, en zeiden geen onvertogen woord als ik weer voor een week naar Slangenburg ging. Tom, jij kan een bijna leeg glas in een bijna vol glas veranderen. Roos jij bent super creatief en inspireerde me voor de voorkant. Ik ben trots op twee zulke fijne kinderen.

Cassandra, voor jouw onvermoeibare en onvoorwaardelijke liefde en steun schieten dankwoorden te kort.



Curriculum Vitae

Sander van Egmond, MSc. (1973) studied Science, Business and Policy at Utrecht University. He graduated on energy saving of refrigerators, in particular on the evaluation of the Stirling cooler. During his study he was a member of the University Council and secretary of the Dutch Student Union (LSVb). After his graduation he worked at Greenpeace as a renewable energy campaigner, particularly promoting solar energy. He was involved in placing a (not requested) solar energy system on the roof of the office of the Prime Minster to demand more solar energy. During this period he also campaigned against oil pollution in Siberia, and helped with a sustainable rebuilding of a school after the earthquake in Gujarat, India. Later he worked at Utrecht University as lecturer and coordinator of the Master track Energy & Resources, where he also obtained his 'Basic Teaching Qualification'. Afterwards he worked at the unit Policy Studies of the Energy research Centre of the Netherlands (ECN) as a senior scientist, where he led amongst others an EU solar energy research programme.

In 2005 he returned to Utrecht University, where he is involved in managing research projects. Originally he was stationed at the Utrecht Centre for Energy research (UCE), and later at the Utrecht Sustainability Institute (USI). He worked on different kind of energy issues, including energy storage and biomass. The last years the majority of his work involved CCS. As CATO communication manager he is responsible for the dissemination of the results of the programme and he organises numerous workshops and conferences. During these meetings he uses unconventional formats like games, cartoons and drama to increase participation and integration of the CCS community. As communication manager he follows and feeds the public debate on CCS as well, of which this thesis is a spin off.

Sander is married to Cassandra and a proud father of Roos and Tom. In his free time he runs a wood workshop where he designs and fabricates semi-professional furniture (www.infinitodesign.nl).

Annex 1. Abbreviations and Units

k	kilo (10^3)
M	mega (10^6)
G	giga (10^9)
T	tera (10^{12})
P	peta (10^{15})
E	exa (10^{18})

AD	Algemeen Dagblad, Dutch daily newspaper
BECCS	Bio-Energy with Carbon Capture and Storage
CATO	Dutch CCS research programme (CO_2 Afvang, Transport and Opslag)
CCS	Carbon (dioxide) Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CDA	Christian Democratic Appeal
CSLF	Carbon Sequestration Leadership Forum
CU	Cristian Union,
D66	Democrats'66
DCMR	Environmental protection agency Rotterdam Rijnmond area
DOE	Department Of Energy (in the US)
EC	European Committee
ECN	Energy research Centre of the Netherlands
EGR	Enhanced Gas Recovery
EIA	Environmental Impact Assessment
EOR	Enhanced Oil Recovery
ETS	Emissions Trading System for CO_2 in EU
EU	European Union
FD	Financieel Dagblad, Dutch daily newspaper
GCCSI	Global Carbon Capture and Storage Institute
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJ	GigaJoule
GL	GreenLeft
IEA	International Energy Agency
IEAGHG	IEA Greenhouse Gas R&D Programme
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
LCA	Life-Cycle Assessment
MEA	Mono-EthanolAmine, solvent used to capture CO_2
MW	MegaWatt
NGO	Non-Governmental Organisation

NIMBY	Not In My back Yard
NRC	Dutch daily newspaper, NRC Courant
PV	PhotoVoltaics, electric solar energy
PvdA	Partij van de Arbeid, Labour Party
PvdD	Partij voor de Dieren, Party for the Animals
PVV	Partij Voor de Vrijheid, Freedom Party
R&D	Research and Development
RCI	Rotterdam Climate Imitative
ROAD	Rotterdam CCS demonstration project (Rotterdam Opslag en Afvang Demonstratieproject)
SER	Social and Economic Council of the Netherlands
SGP	Staatkundig Gereformeerde Partij, Reformed Political Party
SME	Small and Medium-sized Enterprises
SP	Socialist Party
SP	Sub Programme
TNO	Dutch institute for applied research (nederlandse organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek)
UCE	Utrecht Centre for Energy research
UN	United Nations
UNFCCC	Framework Convention on Climate Change
USI	Utrecht Sustainability Institute
VNO-NCW	Confederation of Netherlands industry and employers
VVD	Volkspartij voor Vrijheid en Democratie, People's Party for Freedom and Democracy
WEC	World Energy Council
WP	Work Package
WWF	World Wildlife Fund

Annex 2. Dutch CO_2 emissions

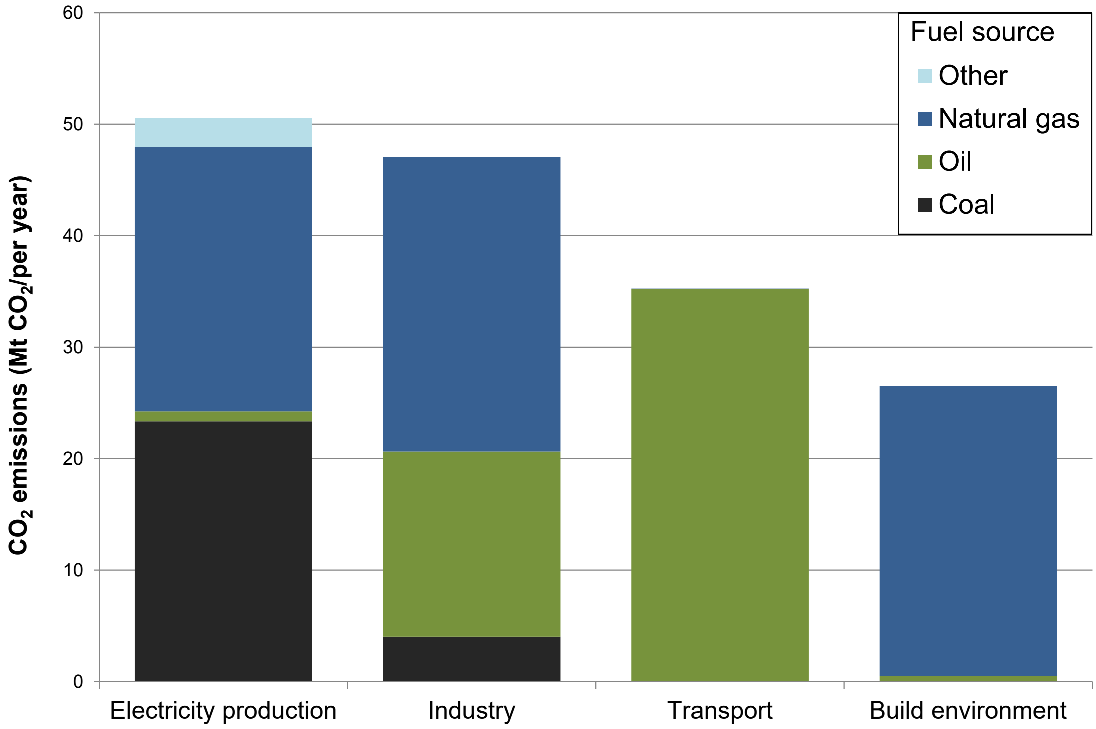


Figure A1. Direct energy related CO_2 emissions in the Netherlands in 2011, split into sector and energy source (RIVM, 2013).

Dutch greenhouse gas emissions equalled 200 Mt CO_2 in 2011 (RIVM, 2013). 10 Mt CO_2 is emitted from non-energy related sources, for example emissions from chemical processes and change in land use. Moreover, emissions of other greenhouse gases, like Methane and Nitric Oxide contributed 27 Mt CO_2 equivalents. Dutch energy related CO_2 emissions were 160 Mt CO_2 in 2011, and separated according to sector and energy source in Figure A1.

The power sector has the highest CO_2 emissions in the Netherlands. Natural gas-fired and coal-fired power plants both contribute approximately 50% of the emissions of this sector. The remainder part is related to oil, blast furnace gases and other fuel sources. The CO_2 emissions from industry are comparable to the emissions of the power sector, but has a much larger oil share, and lower contribution of coal. Both sectors are stationary and emit large amounts of CO_2 per location, allowing for optimal implementation of CCS.

The direct CO_2 emissions from transport are oil based. CCS is unsuitable for this section. To reduce CO_2 emissions from this sector energy efficient vehicles can be developed, combined with a reduction in driven kilometres. Another option is to change the energy carrier in biomass, electricity or hydrogen. The latter two need to be produced elsewhere, which will result in higher CO_2 emissions in the power sector and industry. CO_2 emissions from the build environment are almost completely caused by burning natural gas for heating. The use of (passive) solar energy, green gas and better insulation can reduce the direct CO_2 emissions. Additionally, electricity, and perhaps hydrogen, can replace the natural gas.

Our climate is changing. Carbon Capture and Storage (CCS) has been identified as an important technology to reduce CO_2 emissions in order to avoid dangerous climate change. The implementation of CCS is however slow and CCS is publicly contested. This thesis focuses on the debate on this technology. In fact CCS is not just one technology, but a set of several hundred different CCS chains, having their own advantages and drawbacks. Some consider CCS therefore as a multi tool that can be used in all kind of different applications. For opponents it resembles more a multi-headed dragon, since each time one chain is eliminated, a new configuration arises. This thesis examines how CCS is perceived by the general public, politicians and scientists and unravels the underlying considerations on which their opinions are based.