The difference between the public acceptance of CCUS and CCS in the Netherlands

A qualitative study developing a theory about how the public acceptance of CCUS and CCS would differ in the Netherlands

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Abstract

Carbon Capture and Storage (CCS) is expected to play an important role in reducing CO2 emissions in the short term. CCS involves capturing CO2 from industrial processes, such as steel and cement making, as well as from electricity production, such as at a gas fired power-plant and storing the CO2 underground. Several studies have shown that a problem for CCS is the lack of public acceptance. The lack of public acceptance became evident in the past, causing protests in the Netherlands. A complementary technology to CCS is Carbon Capture Utilization and Storage (CCUS). Instead of immediately storing the CO2 in the ground, the CO2 could be utilized in CCUS. There is not enough information available about the public acceptance of CCUS. Therefore, this research develops a theory about how the public acceptance of CCUS would differ from the public acceptance of CCS in the Netherlands. This is a qualitative research, making use of expert interviews. In total, 5 expert interviews were conducted. Based on the results gathered through the interviews, the following theory was formed: “The public acceptance of CCUS differs in a positive way from the public acceptance of CCS in the Netherlands, since the public has a positive association with circularity, there are less safety risks and the lack of trust in the organization disappears.” This theory needs to be proven in a quantitative research. Next to that, other suggestions for further research are made to address remaining knowledge gaps.

Keywords; CCS, CCUS, CO2 utilization, Public acceptance, Public perception, Netherlands

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Acronym page

CCS: Carbon Capture and Storage

CCUS: Carbon Capture Utilization and Storage

NIMBY: Not in My BackYard

EU: European Union

Introduction

The purpose of this study is to research how the public acceptance differs between Carbon Capture and Storage (CCS) and Carbon Capture Utilization and Storage (CCUS) in the Netherlands. To this day, the information that can be found about the public acceptance of CCUS is inadequate. However, due to the promising role CCUS could play in the sustainable energy transition, it is highly important to gain more knowledge about the public acceptance of CCUS.

This introduction consists of two phases, firstly the necessity of CC(U)S is explained and thereafter a literature review is conducted. In this literature review the applications and implications of CCS and CCUS are explored in depth. The literature review is used to form the research question.

Necessity of CC(U)S

Since the mid-20th century, the earth has been warming up more rapidly than it ever did before. Human activities have contributed to approximately 1.1 degrees Celsius warming, since pre-industrial levels (Arias, et. al; 2021). Scientists have attributed this global warming to the extra greenhouse effect created by humans. Certain gases, greenhouse gases, block heat from escaping the atmosphere. Examples of these gases are: Water vapor (H20), Nitrous oxide (N20), Carbon dioxide (CO2) and Methane (CH4) (NASA, 2020).
The combustion of fossil fuels, such as gas, coal and oil, gives energy to a lot of today's practices such as heating houses, creating electricity, powering vehicles and many more. However, due to this combustion, greenhouse gases, mainly carbon dioxide, are released into the atmosphere. Global warming has severe consequences for a lot of regions and people across the world. The next paragraph will list a few of the most severe problems.

First of all, the sea level rises. This is due to the melting of glaciers, resulting in an even warmer climate since the albedo of water is lower than that of ice. Secondly, because of the expanding water in the oceans, due to higher temperatures.
Another problem due to climate change is the fact that more extreme weather events will occur more frequently and more severely.

Lastly, there will be huge changes in precipitation all over the world. There will be more precipitation in already wet areas, resulting in floods and less in dry areas, resulting in droughts (NASA, 2020).

In the Paris agreement in 2015, the upper limit of 2 degrees warming compared to the pre-industrial era was set in a legal instrument for the first time. In addition, the aim is to limit warming to 1.5 degrees (Paris agreement, 2015). According to a recent research by the IPCC, the global temperature is expected to exceed 1.5 degrees Celsius within the next two decades (Arias, et. al; 2021). However, this same report also states that humans are still capable of determining the course of the climate. If humans were to take aggressive action immediately and achieve zero net emissions in 2050, the global temperature could rise to 1.6 degrees Celsius above pre-industrial levels by 2050 and decrease to 1.4 degrees Celsius by the end of the century (Arias, et. al; 2021). In order to reach this goal, a maximum 400 gigatons CO2-equivalent can be emitted from now on. However, currently 36.4 gigatons CO2-equivalent per year is emitted worldwide (Arias, et. al; 2021). This means that in 11 years' time this threshold will be passed if humans continue as they are doing today.
Meeting this goal is only possible if all industries become carbon neutral as soon as possible. This cannot be met by relying solely on renewable energy (Arias, et. al; 2021).

The Paris agreement required the 197 states that signed the agreement to draw up national climate plans (nationally determined contributions, NDCs) that were ambitious and whose level of ambition should increase with each new plan. The EU and its member states are committed to cutting down their greenhouse gas emissions by at least 55% by 2030 from 1990 levels (IPCC, 2019). Since the Netherlands is a member state of the EU, this reduction is also required for the Netherlands.

Figure 1 shows the total CO2 emissions of the Netherlands in the period 1990-2020. In 1990 the total CO2 emissions amounted to 162.7 Megaton. In 2017 this was still more with 163.1 Megaton, and since 2017 this started decreasing to 138.1 Megaton in 2020. This shows that a downward trend has started, however new data shows that the amount of greenhouse gas emissions will increase again in 2021 (RIVM, 2021). This is due to the fact that in 2020 the COVID-19 virus came up and countries closed their borders to almost all travelers and people were often obliged to work from home. Subsequently, the transportation sector emitted less greenhouse gases. However, the COVID measures have decreased last year and people started traveling more again, therefore the total CO2 emissions are expected to increase again in 2021 (RIVM, 2021).

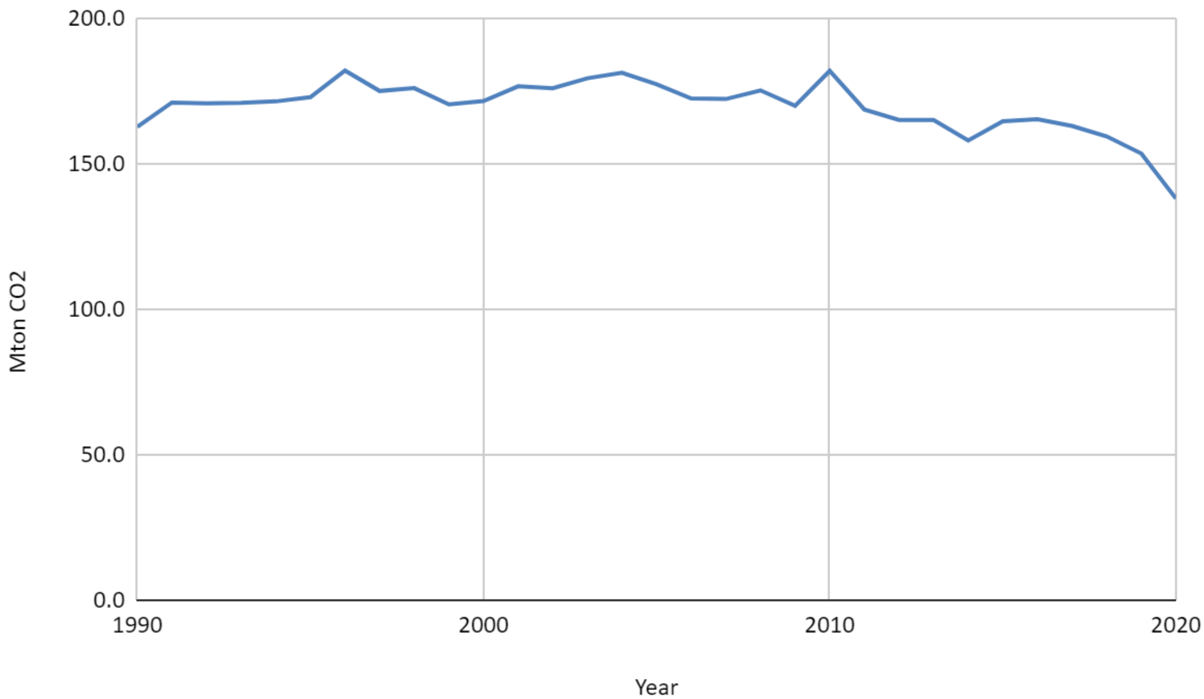

Figure 1: Total CO2 emissions of the Netherlands in the period 1990-2020 in Megaton CO2 (retrieved from RIVM, 2021)

In 1990 the total emissions amounted to 220.5 Megaton CO2-equivalent (RIVM, 2021). By 2020 this has decreased by 25.4% to a total of 164.5 Megaton CO2-equivalent (RIVM, 2021). An important aspect to pay attention to is that most of the decrease in greenhouse gas emissions was due to a decrease in other greenhouse gasses, such as CH4, N2O and fluorine-containing gasses, rather than a decrease in CO2 emissions (RIVM, 2021). The total emissions of CH4, N2O and fluorine-containing gasses has decreased by 54,3% in the time period 1990-2020 (RIVM, 2021). This is mostly due to less methane emissions from landfill sites (11 Megaton CO2-equivalent), fewer emissions of F-gasses due to their elimination in the late 1990s (7 Megaton CO2-equivalent), fewer nitrous oxide emissions due to measures in nitric acid production in 2008 (6 Megaton CO2-equivalent) and less methane emissions from oil and gas extraction (1 Megaton CO2-equivalent). In order to achieve the climate goal of the reduction of greenhouse gas emissions with 55% by 2030 from 1990 levels, the CO2 emissions have to drastically reduce.

Figure 2 shows the percentage of greenhouse gasses emitted per sector in the Netherlands in 2020. Over half of the greenhouse gas emissions are emitted by the industry and the electricity production sectors. The third most emitting sector is transportation, closely followed by agriculture and housing. (Rijksoverheid, 2021)

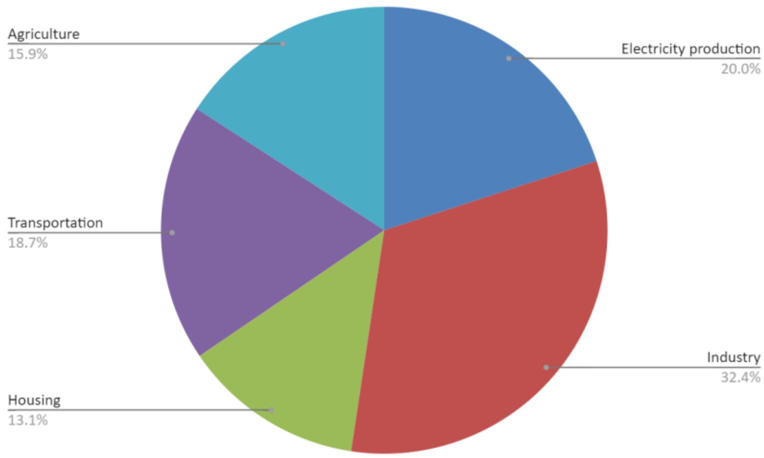

Figure 2. Greenhouse gas emissions by sector in the Netherlands in 2020 (Rijksoverheid, 2021)

In order to reach the goal of cutting down greenhouse gas emissions by at least 55% by 2030 from 1990 levels, all these sectors have to decrease their amount of emissions (IPCC, 2019). For instance, the electricity sector is undergoing a large-scale energy transition. Currently 88.94 percent of the energy is non-renewable, mostly produced by gas fired power plants, followed by coal fired power plants and nuclear energy (Rijksoverheid, 2021).

The amount of renewable energy in the Netherlands is growing fast as is shown in figure 3. In 2020 the percentage of renewable energy from the total energy used is 11,06 percent. More than half of the renewable energy mix consists of biomass, followed by wind and solar energy and lastly a small percentage is produced by other renewable energy sources, such as hydropower, geothermal energy and outdoor air energy (Rijksoverheid, 2021).

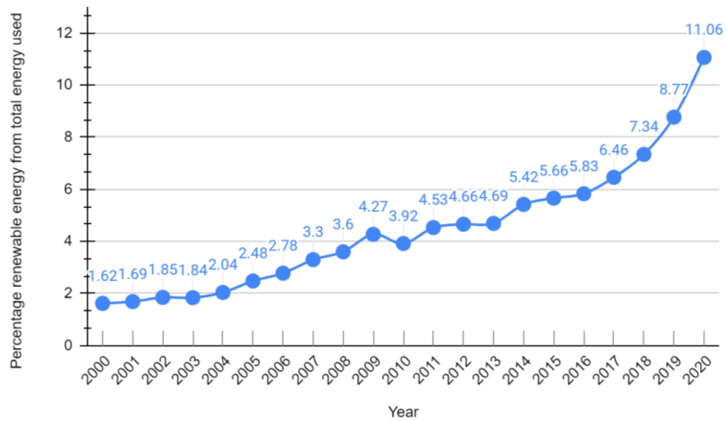

Figure 3. Percentage of renewable energy from total energy used in the period 2000-2020 (Rijksoverheid, 2021)

Another promising way of cutting emissions without revising technologies in all sectors is by using Carbon Capture and Storage (CCS) technology. CCS is the underground storage of captured carbon dioxide gas that is released during the combustion of (fossil) fuels. CCS is a technique with which fossil fuels can be used (almost) climate neutrally (Growth, 2018). By capturing the CO2 at an emission point, CO2 that arises from the combustion of hydrocarbons and storing it in underground reservoirs, such as depleted gas fields, the process prevents the CO2 from ending up in the atmosphere (Growth, 2018). CCS can be used complementary to other technologies in the sustainable energy transition.

Research question

A complementary technology to CCS is Carbon Capture Utilization and Storage (CCUS) (Olah, 2005). Instead of immediately storing the CO2 in the ground, the CO2 could be utilized. The information and literature that can be found about the public acceptance of CCUS is insufficient. To my knowledge, there are currently no studies on public acceptance of CCUS. Therefore the research question of this paper is as follows:

"How would the public acceptance of CCUS differ from the public acceptance of CCS in the Netherlands?"

Literature review

The literature review consists of four sections; first of all, the CCS concept is explained. This part consists of the applications of CCS and the CCS projects in the Netherlands. Secondly, CCUS is explained. Then the issues related to the public acceptance of CCS are discussed and the last section focuses on the forming of the research question.

Carbon Capture and Storage

The most widespread technology used for capturing CO2 is adsorption. Adsorption is the adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid, in this case CO2, to the surface of another liquid or solid, the adsorbent (Smit, et. al; 2014). For the capture of CO2, zeolites and metal-organic frameworks (MOFs) are often used as adsorbents (Smit, et. al; 2014). The CO2 sticks to the surface of the adsorbent and can later be separated using a swing in the temperature or pressure (Smit, et. al; 2014). Once separated, the CO2 can be transported to a storage location via pipelines.

Applications

With CCS, the power generation, cement, petrochemical and steel industries can operate in the same manner as they currently do, however the CO2 is captured at the site and then later stored for instance in depleted gas fields (Growth, 2018). CCS also allows for blue hydrogen to play a role in the energy transition, this is explained in the next section.

Hydrogen

There are three types of hydrogen, namely grey, blue and green. Grey hydrogen is hydrogen in which the production of hydrogen produces CO2 and these emissions end up in the atmosphere. Blue hydrogen is hydrogen in which the production of hydrogen produces CO2, but this CO2 is captured and stored using CCS practices. In the production of green hydrogen, no CO2 is produced during the process.

Grey hydrogen is hydrogen which is produced using natural gas in a process called steam methane reforming (SMR). In this process, steam is blown through natural gas, causing natural gas molecules to split into hydrogen and carbon dioxide (Mulder & Perey, 2019).

SMR is also used for blue hydrogen, however by using CCS to catch the CO2 produced by SMR and storing it underground, no CO2 will be emitted into the atmosphere.

Green hydrogen is produced by splitting water into hydrogen and oxygen using renewable electricity.

Hydrogen is an ideal energy carrier, because their outer structure enables easy exchange and storage of energy (electrons). Electricity can be derived from dihydrogen when in the presence of specific catalysts, also called electrolytes, which are used to facilitate the exchange of energy between the dihydrogen and the fuel (Liu, et al., 2020). The dihydrogen will liberate two electrons (micro-unit of electricity) which can be used to power machinery or charge batteries (Liu, et al., 2020). After going through the catalyst, the separated hydrogens react with oxygen, producing water. The advantages of this reaction are that it only emits water and it is possible to convert about 60% of the chemical energy into electricity, whereas with regular combustion from oil one would only achieve 20% (Liu, et al., 2020). The remaining chemical energy in both reactions is released as heat (Liu, et al., 2020).

As mentioned before, only eleven percent of the electricity is sustainable electricity. This is not enough to produce green hydrogen. Blue hydrogen could be produced without emitting CO2 into the atmosphere, and this allows for the hydrogen infrastructure to improve. The hydrogen could be used to power large vehicles, such as trucks and to make other industries, such as the steel industry, more sustainable (Mulder & Perey, 2019).

CCS projects in the Netherlands

Figure 4 shows the location of six CCS projects in the Netherlands. The four on-shore projects, Barendrecht, Sebaldeburen, Boerakker and Eleveld were all canceled in the planning phase due to public resistance. These cases will be discussed in the public acceptance section. The other off-shore projects are discussed below.

Figure 4. CCS projects in the Netherlands

The Netherlands was the first country in which the injection of CO2 in depleted gas fields was operationalized (Vandeweijer, et. al; 2018). From 2004 until 2017, the operator (GDF SUEZ E&P Nederland) and TNO worked on a demonstration project in the K12-B field in the North Sea to reinject CO2 into the gas field from which it was produced. K12-B was the first location worldwide where this technique was applied (Vandeweijer, et. al; 2018). The project is now finished without any protests, or public resistance in the thirteen years of service (Vandeweijer, et. al; 2018).

Another big CCS project in the Netherlands is currently being developed. Port of Rotterdam CO2 Transport Hub and Offshore Storage (Porthos) is developing a project in which CO2 from industry in the port of Rotterdam will be transported and stored in empty gas fields under the North Sea (Porthos, 2021). The technical details of this project will be described below. These details will give a clear view of the steps taken in such a project, therefore the part of what does not appeal to the public will become clearer.

The CO2 transported and stored by Porthos is captured by various companies, namely Air Liquide, Air Products, ExxonMobil and Shell. (Porthos, 2021) Capture takes place at these refineries and hydrogen producers in Rotterdam. The companies supply their CO2 to a collection pipe that runs through the Rotterdam port area. The CO2 will then be pressurized in a compressor station. (Porthos, 2021). A pipeline runs from the compressor station to the gas extraction platform P18-A in the North Sea (Porthos, 2021) . The facilities necessary to direct

the CO2 to the injection wells will be installed on the platform. The CO2 is stored in the pores of the sandstone. This sandstone used to be filled with natural gas, however this gas has been extracted and used for heating and other purposes (Porthos, 2021).
The gas has been hermetically sealed under high pressure for millions of years by the caprock and the closing fault lines. This pressure has decreased due to the gas extraction and will increase again due to the injection of CO2 (Porthos, 2021). Monitoring and control ensures that the pressure in the reservoir never exceeds the level from when gas extraction started. (Porthos, 2021) The CO2 is introduced into the empty gas field via a well. After the CO2 injection has been completed – when the reservoir is full and at the correct final pressure – the wells are closed with plugs (Porthos, 2021).

Another planned project is Aramis, this project focuses on the transportation of the CO2 from the industry towards the storage site, but does not account for the capture or storage of CO2. This project is also located in the port of Rotterdam area.

Carbon Capture Utilization and Storage

A complementary technology to CCS is Carbon Capture Utilization and Storage (CCUS) (Olah, 2005). This builds on CCS, since an extra step is added to the process. Instead of immediately storing the CO2 in the ground, the CO2 could be utilized. There are several options in which this CO2 can be used.

CCUS counts as an important basic technology for the recovery of carbon neutral fuels in fully regenerative energy systems. The most promising one being methanol fuel, this can be produced by using the captured CO2 and electricity coming from renewable energy sources. This fuel could potentially be used as a fuel for power generation, resulting in a green cycle (Olah, 2005). The CO2 is used to create methanol, which in result is combusted, releasing CO2. This CO2 is consequently captured and could be used to create new methanol, resulting in a closed circle.

Subsequently, another option is to use the CO_2 to create microalgae. These microalgae will be created in a pond and fed with CO_2. This allows the algae to grow quickly while taking up the CO_2. The algae are then harvested and used for biofuel (Hasan, et. al; 2015).

CO_2 can also be used for the production of urea, salicylic acid and cyclic carbonates. These materials can be used in several products, for instance urea can be used to produce fertilizers, salicylic acid can be used to treat acne and cyclic carbonates can be used in lithium batteries (Brinckerhoff, 2011) .

A fourth option is to mineralize the CO_2 using chemical reactions with minerals such as magnesium oxide and calcium oxide to form stable solid carbonates. These carbonates can be used in construction and consumer products (Hasan, et. al; 2015). When used in building materials, it is also referred to as permanent utilization (Hasan, et. al; 2015).

Another option is to inject captured CO_2 into oil fields in a process called enhanced oil recovery. This can result in an increased amount of oil output from the oil field (Hasan, et. al; 2015). However, this would mean that the CO_2 is used for the retraction of oil, which will eventually pollute the environment (Hasan, et. al; 2015).

Lastly there is an option to sell the CO_2 to soft drink companies who can utilize the CO_2 to create sparkling drinks (Hasan, et. al; 2015).

If the CO_2 cannot be used for another purpose, it will still be stored in the same way as CCS in order to achieve zero greenhouse gas emissions (Hasan, et. al; 2015).

Public acceptance CCS

Deployments of CCS systems are regularly threatened considerably by public protests. Especially in Europe, some planned CCS projects and even efforts for exploration of storage potentials have evoked substantial protest among citizens (Desbarats et al., 2010; Dütschke, 2011). In the mid-late 2000s a number of planned small- to large-scale CCS projects began to encounter opposition from local communities in several European countries and were either canceled, or went ahead in a reduced or restructured form (Bäckstrand, Meadowcroft, Oppenheimer; 2011).

For the purposes of this study, the definition of public acceptance of CCS is derived from the research conducted by Kim et. al, 2014 about the public acceptance of nuclear power. It can be defined as people's willingness or readiness to receive the operation of CCS, as determined by perception-sharing. “Perception” and “sharing” are the two most important concepts expressed in the definition. With regard to perception, the public acceptance of CCS is subject to objective evaluation, as well as the subjective perception of individuals. In terms of sharing, individual factors, as well as complex social, cultural, and historical factors are taken into account when determining the public acceptance of CCS (Kim et. al, 2014). An example of this is the distance between a home and a CCS project.
The four most important factors, determined in the research by Kim et. al, that influence the perception are; public awareness, trust, risks, and benefits.

First of all, public awareness refers to the knowledge the public has about CCS. This entails the technology itself, the applications of CCS as well as about the monitoring of the storage. A high level of awareness, allows people to objectively weigh the benefits and risks related to CCS. The second important factor is trust. Trust is about the belief in the reliability of the organization conducting the CCS project and/or conveying information regarding CCS. More trust results in a higher public acceptance of the technology. Thirdly, the factor of risks is about the perceived risk of an individual that may be affected by fear, control, seriousness, familiarity, or conviction. A higher perceived risk leads to less public acceptance. And lastly, the factor of benefits is about the perceived benefit of an individual regarding CCS. A higher perceived benefit, results in more public acceptance of CCS.

According to a research conducted by Shell, the government, industry and environmental NGOs, have a positive attitude towards CCS technologies in the Netherlands (van Alphen, et. al, 2007). Although most environmental NGOs see CCS technology as an effective option to achieve the required carbon dioxide reductions, it is not their first choice (Lipponen et. al, 2017). Their acceptance of CCS can be characterized as ‘reluctant’ rather than ‘enthusiastic’ (Lipponen et. al, 2017). That raises the question under what conditions is the public in the Netherlands reluctant to the use of CCS technologies.

First of all, there is the problem of public awareness. A study conducted in 2021 in the Netherlands and the United Kingdom shows that 86.5 percent of the respondents in the

Netherlands have hardly any knowledge about CCS or have never even heard of it (Broecks, et. al 2021). This study was to measure the public knowledge and acceptance of CCS in the Netherlands and the United Kingdom via surveys. The respondents were divided into two different pools, namely the general public and public living close to industry. However, no statistical significant differences were found in these two groups.

These results show that most people do not have an opinion formed about CCS yet. Therefore, it is hard to collect reliable data about the public acceptance of CCS. However, this study has tried to do exactly that. The results of the study show that the public opinion about CCS in general in the Netherlands is neutral to slightly positive.

The research had also taken the reasoning of the participants into account. The most used argument in favor of CCS is, “Climate change/environmental benefits.” This argument was used by 41.1 percent of Dutch respondents. Two other arguments that were used were ``Best available/temporary solution” and “Climate change action needed`` with 19.1 and 17.7 percent respectively.

The three most used negative arguments were, “safety/risk/monitoring concerns”(44.5%), “support alternatives to CCS (e.g. solar panels)”(20%) and “CCS does not solve the problem, it is a short term solution”(13.6%).

Arguments for neutral votes were mostly that they needed more information, phrased in different ways, or that the Netherlands is a small country that it would have no effect on the environment.

Another study like this has been conducted in the past, namely a research conducted by Wallquist et. al in 2012.
In this research 139 Swiss participants were asked questions regarding their opinion on CCS in their living area. This was solely for research purposes and not because there was a plan to build a CCS installation in the corresponding area. The researchers assumed that there would be little knowledge about CCS in their sample, therefore they used an introductory text about the essence of CCS. In this research the questions were based on three factors, namely type of plant, storage location and type of pipeline. The options for type of plant were, gas fired, or biogas fired, the options for storage location were, in their own municipality, or in a neighboring canton, the options for pipeline were gas pipeline, CO_2 pipeline, or no pipeline. The sentences

were constructed as follows: “CO2 from a biogas-fired power plant is stored in the subsurface of your municipality. Near your house passes no pipeline.” In total there were 12 hypothetical scenarios and these were presented to the participants in a random order. (Wallquist et al, 2012)

The research showed that the participants strongly disfavored a pipeline running close to their house. For the type of plant, the biogas-fired power plant was favored over the gas fired plant and there was not a significant preference for the location of storage. For the pipelines, a not in my backyard (NIMBY) effect could be observed. NIMBY means that the public is not in particular against the idea or technology, but they do not want to have it close to their home. This is stronger for a gas pipeline than for a CO2 pipeline. This is surprising because other research is mostly focused on the storage part of public acceptance (Wallquist et al, 2012). However there is a small preference for storage in the neighboring canton over their own municipality. (Wallquist et al, 2012)

However, not all information about public acceptance is merely theoretical, a plan existed to store CO2 in the Netherlands twelve years ago, namely in Barendrecht in 2010 (Brunsting, et. al; 2011). This was a plan by Shell to store CO2 in an depleted gas field under an existing neighborhood in the city of Barendrecht in the Netherlands (Brunsting, et. al; 2011). The government of the Netherlands would subsidize this project and was in favor at first, however due to massive resistance from the local residents and the local council, these plans were canceled (Brunsting, et. al; 2011).

In the case in Barendrecht there were several complaints from the public, they submitted these complaints to the municipality who published a list. (Brunsting, et. al; 2011).
First of all, the location. The municipality argued that it was not logical to locate the first on shore CCS installation in a densely populated area like Barendrecht (Brunsting, et. al; 2011). The municipality of Barendrecht has 1.680 addresses per km2 (Allecijfers, 2022).
Secondly, there were complaints about the monitoring of the stored CO2. This monitoring means that there would be no leakages and the pressure would not be too high. The government of the Netherlands and Shell had already come to an agreement on this topic, however there was little confidence from the public in the proper organization for the monitoring. (Brunsting, et. al; 2011).

As a third complaint the municipality stated that the safety was based on a model and not on real life experiences. To add to this complaint, the municipality claimed that the model was incomplete since it did not include morbidity issues such as illness and psychosomatic effects on public health (Brunsting, et. al; 2011).
Lastly, there were economical complaints, for instance regarding the real estate value and the fact that 'the polluter', in this case Shell, would hugely benefit from this project whereas the public would not and this was considered unfair. (Brunsting, et. al; 2011).
These complaints were later confirmed by a large-scale survey conducted in Barendrecht. This survey was conducted right before the decision to cancel the project (Terwel et. al, 2012).

If Shell could solve or guarantee all these complaints, the project would get a green light. Shell started spreading information about the safety of the project through local newspapers and had an information stand in a local mall (Brunsting, et. al; 2011). However, this had an opposite effect. Several local political parties continued to protest against the project and more people joined these protests, resulting in nationwide attention in newspapers (Brunsting, et. al; 2011). In the newspapers an expert stated that there were still a lot of uncertainties regarding the safety of CCS, resulting in even more protests. (Brunsting et. al; 2011). Therefore, people started to mistrust the information Shell was providing. (Brunsting et. al, 2011)

Due to a change in the Dutch law, the decision making was suddenly no longer in the hands of the municipality, but in those of the national government. (Terwel et. al, 2012) The government gave green light and held an informational meeting in Barendrecht, which led to even more protests. In the end, the project was canceled by the Dutch government due to the massive public resistance. (Brunsting et. al, 2011 ; Terwel et. al, 2012) Shell then started to look into different options for onshore CCS in the Netherlands. They investigated three towns in the north of the Netherlands, namely Boerakker, Sebaldeburen (neighboring villages) and Eleveld, however these options were quickly met with public resistance and were therefore immediately canceled. (RTV Noord, 2010; Terwel et. al, 2012)

The municipality and the public were informed and included much too late in the project and were not given an equal voice in the process (Brunsting et. al, 2011 ; Terwel et. al, 2012). Those are possible explanations of the massive protests by the people in Barendrecht. On top of the fact that the local population did not want to live on a CO2 storage site, since it was such a new concept. (Brunsting et. al, 2011 ; Terwel et. al, 2012)

Below the findings regarding the public acceptance issues of CCS will be summarized and linked to the two concepts of perception and sharing, which form the public acceptance.
First of all, the public opinion about CCS in general in the Netherlands is neutral to slightly positive. This is because the public generally sees that climate action is needed and that CCS is currently the best available/temporary solution (Broecks et. al, 2021). This is positively related to the perceived benefits that form the perception the public has about CCS.
However, when a project, or pipeline is close to home, issues start to appear, this could be attributed to the NIMBY effect and this is additionally a part of the concept of sharing (Wallquist et al, 2012; Kim et al, 2014).
The most important argument regarding the NIMBY effect against CCS is the safety concern, related to the risks one perceives from a CCS project. This was monitored in the Barendrecht case as well as in the research of Broecks et. al in 2021.
Other important issues were the distribution of costs and the lack of trust in the organization conveying the information (Brunsting et. al, 2011). The distribution of costs is related to the concept of sharing, since the public generally does not want to pay for CCS as shown in the research of Broecks, et. al, 2021. The lack of trust relates to the factor of trust.
On top of that there is the problem of public awareness. The study that was conducted in 2021 in the Netherlands and the United Kingdom by Broecks et. al, shows that 86.5 percent of the respondents in the Netherlands have hardly any knowledge about CCS or have never even heard of it. Next to that, the citizens in Barendrecht were not in time informed about the project and what it exactly entailed (Brunsting et. al, 2011).
Lastly, the public would rather see investments in “long term sustainable solutions,” such as solar panels, rather than in a “short term solution such as CCS” (Broecks et. al, 2021). This negatively impacts the perceived benefits.

As mentioned before, CCUS could allow for the CO2 to be used to the fullest extent before eventually deciding on the option for the CO2 to be stored underground. Therefore, the issues regarding safety, and subsequently the issues regarding the NIMBY effect will be eliminated. The aspects that are not changed are the pipelines and the storage after the utilization, if this storage is close to ones’ home. However, projects like Porthos could then be used to store the CO2 underneath the North Sea, instead of on land underneath cities. CCUS could be seen as a long term sustainable solution, since the CO2 can be used in different sustainable ways.

Methodology

In this study, the public acceptance of CCUS in comparison to the public acceptance of CCS was researched in depth. The goal was to identify how the public acceptance differs between Carbon Capture and Storage (CCS) and Carbon Capture Utilization and Storage (CCUS).

After discussing the techniques and theories behind CCS and its public acceptance in an extensive literature review, semi structured in depth interviews have been conducted and gave an insight into the difference between the public acceptance of CCUS and the public acceptance of CCS. The choice for a qualitative research method rather than a quantitative research method was because the tools were not at hand to conduct a heterogenic survey for the complete population of the Netherlands. Therefore, in depth interviews were conducted with experts in the field of CCS and CCUS.

The number of participants was five. This is a rather small sample, however this is due to the limiting time and limited number of positive replies to the contacting attempts. These interview partners were identified using LinkedIn, the literature review and through directly contacting companies. As shown in table 1, the experts were from different backgrounds.

Sector	Function
Academia	Researcher CC(U)S
Industry (energy sector)	Business opportunity manager
Academia	Researcher CC(U)S
Dutch CCS project	Public affairs adviser
Academia	Sustainability adviser

Table 1. Background participants interviews

With the participant’s permission, the interviews have been recorded, with the promise that after transcription of the interviews, the recordings were to be deleted. All identifying files have been deleted upon completion of the thesis. Since all interviewees are Dutch, the language in which the interviews were conducted was also Dutch. The transcripts were not translated to English as this would risk losing implicit messages due to translation. All interviewees have been notified about the confidentiality, and will remain anonymous. Before the interview, they were notified about the fact that they could stop and/or leave the interview whenever they wanted. The data collected from the interviews are stored on the Y-drive of the University of Groningen.

The interviews took place in February and March 2022, and the interview consisted of 21 prepared questions. The exact amount of interview questions differed per interview, since the experts touched upon different topics which through the semi-structured design allowed for probing questions. All prepared questions can be found in the interview guide in appendix A. Two examples of the questions translated to English are:

1. *"Is CCS generally accepted by the public, and why (not)?"*
2. *"Do you think the public acceptance would be different for CCUS, and why (not)?"*

The interviews have been transcribed in Dutch and from this transcription, coding has been developed in English. The codes were either deductive, retrieved from the literature review, or inductive, retrieved from the participants input. After this the codes were categorized in the codebook. The results were then displayed in the results section and discussed in the discussion section. Throughout the discussion a theory about the difference between the public acceptance of CCUS and CCS in the Netherlands was formed, this theory was formulated in the conclusion.

Results

In this section the results of the interviews will be presented. These results are derived from the codes attributed to the transcriptions; a list of these codes can be found in the codebook in Appendix B. Firstly, the ideal storage location according to the experts will be discussed. Secondly, the wide range of opinions within the public. After that, the results will be structured through the four factors that determine the public perception of CCS presented by Kim et al, 2014, namely; public awareness, trust, benefits and risks. Lastly, the results regarding the concept of sharing, that are related to the individual factors, complex social, cultural, and historical factors, are presented.

Ideal storage location

First of all, the experts agreed that the ideal CO2 storage location is offshore. They mentioned that onshore storage will not happen in the Netherlands and the only option is offshore. This is due to the protests that have been caused by onshore storage in the past in the Netherlands. Added to the offshore storage location is that there should be a good infrastructure in place, which could be reused for the storage of CO2. This infrastructure could consist of old gas pipes as well as old gas extraction platforms on sea.

Wide range of opinions

One participant mentioned that *“Nobody will cheer and say thanks for storing those few tons of CO2 underground.”* They meant that the ideal scenario would be that there are no protests against CCS. This is because there is a wide range of opinions within the public and to improve the public acceptance of CCS, one should try to convince the middle ground, i.e. the people without an opinion formed. This could be done through early engagement. “*So as soon as you know that somewhere nearby CO2 is going to be captured, or stored somewhere nearby, you start a conversation with anyone who could be affected by it.”* This should happen in the earliest stages of planning, in order to prevent the forming of negative opinions by the public.

Public awareness

Several experts talked about the lack of knowledge. Their arguments differed in meaning, since some stated that more knowledge does not lead to more acceptance. *“As long as we give enough information about what it is and that it is safe, people will understand that, but it doesn't work that way.”* Whereas others talked about how the public should know more about CCS in order to form a better opinion.

Trust

Another argument that was mentioned by the participants is that of trust. *“Trust in the sender, for example, which can play a fairly large role (when forming an opinion).”* Trust in the organization that is conveying the information, as well as trust in the organization operating a project, regarding CCS were talked about. The trust in the organizations conducting CCS in the past was generally low, resulting in lower public acceptance.

Benefits

The experts talked about several benefits for CC(U)S, all these benefits could contribute to one's opinion on CC(U)S. First and foremost, the necessity of CC(U)S. The experts mentioned that CC(U)S is necessary to bridge the gap between the climate goals and the current emissions. This does not mean that there should not be investments in other measures, such as solar power, as well, but rather that CCS should act as a complementary technique to these solutions. Several experts talked about this necessity and they said that this was the strongest argument the public gave in favor of CC(U)S.

Several experts stated that the applications of CCS matter when one is forming an opinion about CCS. The most mentioned application was that there are currently no alternatives to the technologies that allow for making certain products. *“But there is currently no alternative for certain techniques, so if you don't capture, transport and store that CO2, it will simply go up in the air and you will not achieve certain objectives.”* CCS could play a role in sustaining the production of these products, by preventing the CO2 from entering into the atmosphere.
CCS also allows for blue hydrogen to play a role in the energy transition. *“To get green hydrogen on a large scale, you have to produce so much more green electricity. And you just can't manage that, and while you need to develop enough renewable electricity in that period,*

you can already start production and use, especially, but in the form of blue hydrogen or turquoise hydrogen, or other colors, which you certainly do not get from green electricity.” This could help improve the hydrogen infrastructure and therefore help make large vehicles become climate friendly and allow for certain types of industry to move to a sustainable production method.

On top of that, the experts agreed on the arguments related to the climate contribution. The public takes the climate contribution into consideration when forming an opinion about CCS. CCS results in net-zero emissions, therefore this climate contribution is seen as a benefit. Next to that the participants mentioned the possibility to achieve negative emissions through direct air capture where the CO2 is directly captured in the air and stored underground. This argument does not always count for CCUS as well, the experts mentioned that there could still be emissions in certain ways of CO2 usage, such as in the greenhouses, or in biofuel. It would count if the CO2 is used permanently in for instance building materials.

The experts agreed that the circular aspect of CCUS has the biggest different influence on one's perception of CCUS in comparison to CCS. This circular aspect also comes back in the CCUS applications that were mentioned by the experts; greenhouses, biofuel and the permanent utilization of CO2. The experts mentioned the option of creating biofuel out of CO2 as well as the permanent utilization in building materials such as cement. These are two of the most promising applications of CCUS according to the participants. An expert talked about how “waste management” is not an appealing concept: *“Capturing CO2 and then storing it is just waste management, that's not sexy, while if you continue that reasoning, it's just really important, because we really can't do without our garbage collection service. But uhm if you can make something, that seems fantastic.”* Whereas reusing this CO2 would be “fantastic.” Currently in the Netherlands, Shell provides CO2 to greenhouses in the Westland. If Shell would not deliver this CO2, the greenhouses would create this CO2 themselves. Therefore, through CCUS there are currently less emission points. This is the only CO2 utilization project the experts knew of in the Netherlands today.

Risks

First of all, the participants mentioned that the public is scared of the potential safety risks. Mostly the risk of the CO_2 escaping the storage site, but also the risk of a CO_2 pipe bursting was mentioned.

On top of that, there is the risk of lock in; namely that the public could be scared that CCS is used as a permanent solution rather than a bridging solution, which removes the need to innovate towards a more sustainable practice.

Sharing

First of all, one argument that was mentioned the most was that the public would rather invest in long term sustainable solutions, such as solar power, than investing in a temporary solution such as CCS; *"The question of where do you as a government put your money, so what is still being discussed, do you want to put a billion in CCS, or do you want to put your money in a solar park."* This argument is closely related to the argument of the temporary measure, namely through the fact that these other measures should eventually be the sole energy source, since those measures are completely renewable. On top of that are the storage locations limited and, therefore CCS should only function as a bridge between the current situation and a completely renewable energy system.

Secondly, the participants stated that the public is concerned about the costs; who pays for the CCS projects. The participants mentioned that CCS as well as CCUS are expensive technologies. Do the costs lie at the government, or at the company that captures the CO_2? *"Most companies will have to finance it completely themselves, and therefore have to have a business case for it themselves, which helps is the SDE++ subsidy, which actually fill the gap in the business case."* Currently this is a mix of both worlds, namely the company sets up a business case and the government pays the gap in the business case through government subsidies. These subsidies are called SDE++ subsidies, SDE stands for Stimulering Duurzame Energieproductie (Stimulating Sustainable Energy Production) and CCS falls under this subsidy. These subsidies are not in place for CCUS, therefore there is currently no business case for CCUS.

Then all experts mentioned the Not In My BackYard (NIMBY) argument. The NIMBY argument is closely related to the arguments of safety and risks onshore. The NIMBY effect is mainly in place due to the fact that the public is concerned about the safety risks of storage close to their home. They are concerned about the duration of storage and what would happen if the CO2 would escape from the storage site. These arguments are not in place when the storage is offshore or when there is no storage at all, such as with CCUS. However, one expert contradicted the NIMBY argument. *“Sometimes you see that there is indeed a lot of resistance with local projects, look at wind energy, while the opinion is generally quite positive, so in itself that is true. But the explanation of it is close, so we don't want it to be oversimplified.”* They found the argument oversimplified. They stated that the distance to a project is also relative. They mentioned that the NIMBY effect is related to the concept of “place attachment.” Meaning that the idea someone has about a certain place matters when one is forming an opinion about a project.

Discussion

In this section the results from the interviews will be analyzed on the basis of the literature review and an answer to the research question will be formulated. Table 2 shows all arguments presented in the results section and how they relate to both CCS and CCUS. If the argument is an argument against, this is shown with a "-". If the argument is an argument in favor, this is shown with a "+". The arguments in orange are both the same for CCS and CCUS, the arguments in black are in favor of CCS, but depend on the way the CO2 is used for CCUS to be either in favor or against CCUS. The argument in red is in favor of CCS, but against CCUS. Lastly, the arguments in green are against CCS, but in favor of CCUS. The table will be discussed underneath the table.

Arguments for CCS	Arguments for CCUS
- Costs	- Costs
- Expensive	- Expensive
- Energy intensive	- Energy intensive
- Lack of knowledge	- Lack of knowledge
+ Necessity	+ Necessity
+ No alternatives	+ No alternatives
+ Blue hydrogen	+ Blue hydrogen
+ Climate contribution	+ Climate contribution
+ Temporary measure	+ Temporary measure
+ Negative emission	~ Negative emissions
+ No emissions	~ No emissions
+ Business case	- Business case

- Safety	+ Safety
- Long term solutions	+ Long term solutions
- NIMBY	+ NIMBY
- Trust	+ Trust
- Lock in	+ Lock in
- Risks onshore	+ Risks onshore
- Duration of storage	+ Duration of storage
- Circularity	+ Circularity

Table 2. Comparison of arguments between CCS and CCUS

This part explains the positions of all arguments, starting with the orange negative arguments, followed by the orange positive arguments etcetera. Firstly, the costs, there is currently no business case for CCUS, subsequently this gap in the business case needs to be bridged. Will the government take this responsibility, or will the responsibility lie at the company capturing the CO2? This should be researched further in future research. Next to that the process of capturing the CO2 is expensive and creating products with CO2 is as well (Budinis et. al, 2018; Hepburn et. al, 2019). The capturing of CO2 stays energy intensive and the utilization of CO2 is energy intensive as well (Liu et. al, 2017). Subsequently, a lot of electricity is required in order to capture and/or store and/or utilize CO2.
Lastly, the argument of lack of knowledge; research has shown that 86.5 percent of the respondents in the Netherlands have hardly any knowledge about CCS or have never even heard of it (Broecks, et. al 2021). This makes it hard to form an objective opinion about CCS. Since CCUS is a complementary technology to CCS, the public will not have the knowledge about CCUS either that should be present to form an objective opinion.

CCUS could play the same role in the energy transition as CCS, namely reducing the emissions in sectors that cannot undergo radical innovations in the short timespan that is left to reach the goals set in the Paris agreement (Growth, 2018; Paris agreement, 2015). For that reason, the necessity falls under the perceived benefit category, likely resulting in more acceptance. The necessity is an argument in favor of CCS as well as CCUS. The argument that there are no alternatives to certain technologies also applies for CCUS, since CCUS can also capture this CO2 and instead of storing it, utilize it. This accounts for the power generation, cement, petrochemical and steel industries that can operate as they are currently doing, without having to undergo radical innovations and investments (Growth, 2018). On top of that it allows for blue hydrogen to play a role in the energy transition (Mulder & Perey, 2019). Blue hydrogen could be produced without emitting CO2 into the atmosphere, and this allows for the hydrogen infrastructure to improve. These are arguments that fall under the category of benefits.

Next to that could the climate contribution increase in comparison to CCS, since the CO2 will not go to waste, but will be used as a product or fuel. If the CO2 is used as a product, or if the fuel is used in a green cycle, as described in the literature review, the CO2 will achieve net zero emissions and if the CO2 is directly captured out of the air, it could achieve negative emissions. However, if the CO2 is used to create a biofuel and this biofuel is combusted without capturing the CO2 once more, this CO2 will still end up in the atmosphere. The same accounts for if the CO2 is used at the greenhouses. This raises the question whether it matters what the CO2 is used for for the public acceptance of CCS. This should be investigated in future research.

The only argument that is in red is from the business case. The experts stated that the business case for CCS is improving and that the current gap in the business case is being bridged by the government. However, the gap in the business case is not bridged by the government for CCUS. Therefore there is currently no business case for CCUS. How this could be improved, should be researched in future research.

The argument against CCS that one would rather invest in long term solutions is not viable for CCUS, since CCUS is a long term solution itself. This is the case when the CO2 is used circularly, for instance in building materials or in biofuel with the combination of CCUS again, resulting in a green cycle, as described in the literature review (Hasan, et. al; 2015). On top of that the public generally has a positive association with the word circularity (Kostakis & Tsagarakis, 2022). On top of that, through the utilization of CO2 the carbon can still be stored in the form of permanent utilization (Hasan, et. al; 2015). And through the use of CCUS in combination with biofuel, a closed green energy cycle can be achieved (Olah, 2005). Both resulting in net zero emissions and if combined with direct air capture, it could achieve negative emissions in the future. CO2 reduction is of public interest, since it can slow down global warming and it is agreed in the Paris climate agreement (Paris agreement, 2015). Resulting in less perceived risks, more perceived benefits and less reasons to mistrust an organization. The experts agreed that circularity is the biggest factor of difference between the public acceptance of CCS and CCUS. Therefore, the perceived benefits will increase.

If the CO2 is used instead of stored underground, NIMBY is no longer an issue, and together with NIMBY the safety, duration of storage and risks onshore are no longer problems. On top of that does the duration of storage not matter, since it is used instead of stored. The only safety issues that could still play a role are those regarding the transportation of CO2 through pipelines, however these pipelines will mostly stay in the industrial areas where the CO2 is also captured (Olah, 2005). On top of that is the fear of lock-in not a problem anymore, since the utilization of CO2 is a sustainable solution. For those reasons, the public acceptance would likely be higher for CCUS than for CCS, since the perceived risk is significantly decreased. The trust issues are also not a problem anymore, since the organizations that were mistrusted are not storing the CO2 underground anymore, but the CO2 will be used to create products. This lowers the perceived risks and increases the perceived benefits.

To summarize, most arguments that are in favor of CCS stay in favor of CCUS. There are several arguments that differ between CCS and CCUS. Overall, a lot of arguments against CCS are not valid arguments against CCUS. The arguments of circularity, that one would rather invest in long term solutions, the lack of trust in the organization conveying the information and the uncertain duration of storage are the most important differences. The perceived benefits are most probably higher for CCUS than for CCS, due to the circular aspect of CCUS and the perceived risks are likely to be lower for CCUS than for CCS, since the CO2 will not be stored, resulting in no risks related to the storage.

Conclusion

To conclude, this qualitative study conducted five in-depth interviews to investigate the difference between the public acceptance of CCUS and the public acceptance of CCS in the Netherlands. The research question was; *"How would the public acceptance of CCUS differ from the public acceptance of CCS in the Netherlands?"* The aim of this research was to create a theory about how the public acceptance would differ between CCS and CCUS.

Answer to research question / Theory

The results have shown that some of the issues inhibiting public acceptance of CCS are not relevant for CCUS, which may imply that the public acceptance between CCS and CCUS differs. This difference can be attributed to several factors. First and foremost, the factor of circularity. Due to the positive association people have with circularity, CCUS might have a higher acceptance than CCS. Secondly, will the trust issues in the organization conveying the information no longer play a role in the public acceptance of CCUS, since the CO2 will not be stored underground. Lastly, the safety risks will disappear if the CO2 is used instead of stored, since the uncertainty of the duration of storage is taken away. Therefore, there are less perceived risks, more perceived benefits and less reasons to mistrust an organization.

Therefore the answer to the research question and subsequently the theory that has been formed through this research is formulated as follows;
"The public acceptance of CCUS differs in a positive way from the public acceptance of CCS in the Netherlands, since the public has a positive association with circularity, there are less safety risks and the lack of trust in the organization disappears."

Limitations and further recommendations

The first limitation is that for this research the means to conduct a quantitative research were not at hand. Therefore, the choice fell on a qualitative research. With a quantitative research, the answer to the research question could have been proven rather than forming a theory. The second limitation is that there was only a limited number of 5 experts participating in the interviews, this was due to the fact that most companies and experts did not reply to the

contacting attempts. Therefore, the theory formed through this research needs to be tested by a quantitative research.
Other questions that arose during this research, but that were beyond the scope of this research are;

- Does it matter what the CO_2 is used for?
    - Would the public acceptance change when the CO_2 is used for either biofuel, for permanent utilization, or other forms of utilization?
- How to improve the business case for CCUS?
    - Will the government take the responsibility to bridge the gap in the business case, or will the responsibility lie at the company capturing the CO_2?
- (How) would CCUS change innovation in the future?
    - Would CCUS change the innovation, or not? Would CCUS improve innovations in the CO_2 utilization sector and oppose the innovations in making technologies sustainable, or not?
    - If the innovation changes, this could have an impact on the public acceptance of CCUS, since it could be seen as a potential benefit or have a negative impact on the benefit factor.

These questions should be answered in future research in order to gain a better understanding of the implementation of CCUS in the future.

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Appendixes

Appendix A
Interview guide Dutch

Goedemiddag!
Ten eerste wil ik u hartelijk bedanken dat u tijd voor mij vrij heeft kunnen maken om dit interview te houden.
Zoals u weet ben ik Don Nijborg en studeer ik op dit moment Global Responsibility and Leadership aan de Campus Fryslan van de Rijksuniversiteit Groningen. Ik ben bezig met mijn scriptie over de publieke acceptatie van Carbon Capture Utilization and Storage (CCUS) ten overstaan van Carbon Capture and Storage (CCS). Over de publieke acceptatie van CCS is al veel onderzoek gedaan en ook in Nederland, maar over de publieke acceptatie van CCUS is dit niet het geval.
Vandaar dat ik u heb uitgenodigd voor een interview.

Ten eerste wil ik melden dat alles wat in dit interview gezegd wordt strikt vertrouwelijk is en ik alleen uw input gebruik als u daar toestemming voor geeft.
Dat brengt mij tot mijn volgende vraag, is het goed als ik dit interview opneem?

De verzamelde gegevens zullen alleen gebruikt worden voor mijn onderzoek en hierbij wil ik u dan ook aanbieden dat ik de resultaten van het onderzoek naar u toe stuur, als u dat wilt.

Heeft u nog vragen voor we het interview beginnen?

Inleidende vragen:
In welk vakgebied bent u actief en wat is uw functie?

Openingsvragen:

Kunt u in uw eigen woorden beschrijven wat CCS is?

Welke voordelen ziet u voor CCS?

Welke problemen ziet u voor CCS?

Wat weet u over CCUS?

Wat zijn de grootste verschillen tussen CCS en CCUS?

Sleutelvragen:
CCS

Wordt CCS algemeen geaccepteerd door het publiek, en waarom (niet)?

Wat zijn volgens u enkele van de belangrijkste aspecten die de publieke perceptie van CCS beïnvloeden?
(Vervolgvraag (indien niet vermeld): NIMBY?)

Denkt u dat de publieke acceptatie in Nederland anders is dan in andere landen?

Denkt u dat er een oplossing is voor de problemen met de publieke perceptie?
En hoe zou dat eruit kunnen zien?

Welk potentieel ziet u voor CCS in Nederland?

Hoe levensvatbaar acht u CCS in de huidige Nederlandse markt vanuit uw perspectief?
Hoe zit het met de financiering of investeringen?
Is publieke weerstand een groot probleem voor de levensvatbaarheid van de technologie?

CCUS

Denkt u dat de publieke acceptatie van CCUS anders zou zijn dan die van CCS, en waarom (niet)?

Wat zijn aspecten die de publieke perceptie van CCUS beïnvloeden?
Maakt het uit waar de CO2 voor wordt gebruikt?

Denkt u dat er een oplossing is voor de problemen met de publieke perceptie?
En hoe zou dat eruit kunnen zien?

Denkt u dat het potentieel van CCUS anders is dan die van CCS? (Waarom niet)

Hoe levensvatbaar acht u CCUS in de huidige Nederlandse markt vanuit uw perspectief?
Hoe zit het met de financiering of investeringen?
Is publieke weerstand een groot probleem voor de levensvatbaarheid van de technologie?

CC(U)S
Wat zou de ideale opslaglocatie in Nederland zijn voor CC(U)S?
Onshore of offshore
Qua infrastructuur
dichtbevolkte gebieden

Slotvragen:

Wat zijn op dit moment veelbelovende projecten met betrekking tot CCS en/of CCUS in Nederland? En is de een veelbelovender dan de ander?

Werkt u momenteel aan een project met betrekking tot CCS of CCUS?

Wil je iets toevoegen aan dit interview?

Bedank de geïnterviewde voor hun tijd

Appendix B

Codebook

Arguments in favor of CCS		
Code	Definition	Frequency
Necessity	Participant describes the necessity of CCS in order to meet the climate goals.	5
No alternatives	Participant describes that there are no alternatives to certain processes that create products.	4
Blue hydrogen	Participant describes the option of using CCS to make blue hydrogen.	2
Climate contribution	Participant describes that the public takes the climate contribution into consideration when forming an opinion on CC(U)S	2
Negative emissions	Participant describes the option of achieving negative emissions using direct air capture in combination with CC(U)S	2
No emissions	Participant describes that an advantage of CCS is that there are no emissions	2

Temporary measure	Participant describes that CCS is only a temporary, bridging, measure.	2
Business case improves	Participant describes that the Business case for CCS is improving.	1
Generally accepted	Participant describes that CCS is generally accepted by the public.	1
Positive tone in science	Participant describes that CCS has a positive tone in science.	1
Arguments against CCS		
Code	Definition	Frequency
Long term solutions	Participant describes that the public would rather see investments in long term sustainable solutions, such as wind or solar energy, rather than CCS.	5
Costs	Participant describes that the public takes the distribution of costs into consideration when forming an opinion on CC(U)S	4
NIMBY	Participant describes that the not in my	3

	backyard effect is an effect that is also present for CCS.	
Safety	Participant describes that the public is concerned about their safety with regard to CCS.	3
Trust	Participant describes that the public might not trust the organization that provides information to the public.	3
Energy intensive	Participant describes that CC(U)S is an energy intensive process.	2
Lock in	Participant describes that there is a risk that CCS will be used as a lock solution	2
No acceptance	Participant describes that a problem regarding CCS is that there is no public acceptance.	2
Risks on-shore	Participant describes that the public sees certain risks with on-shore storage.	2
CCS no business case	Participant describes that there is currently no business case for CCS	1

Duration of storage	Participant describes that it is uncertain for how long the CO2 can be stored in a depleted gas field.	1
Expensive	Participant describes that CCS is an expensive process.	1
Lack of knowledge	Participant describes that lack of knowledge is a reason for a lack of support.	1
Removes innovation	Participant describes that CCS might remove the need for innovation in non-sustainable sectors.	1
Resistance	Participant describes that there is a lot of resistance to CCS in certain areas.	1
Short term solution	Participant describes that CCS is seen as a short term solution.	1
Arguments in favor of CCUS		
Code	Definition	Frequency
Circularity	Participant describes that the public could perceive the U in CCUS as circulair/recycling	9

Positive view of circularity	Participant describes that the public has a positive view of circularity.	5
Greenhouses	Participant describes the use of greenhouses when talking about CCUS	3
Biofuel	Participant describes the option of converting CO2 into a biofuel.	2
Less emission points	Participant describes that due to CCUS there will be less emission points.	2
Permanent utilization	Participant describes the option of storing CO2 in materials, such as cement or steel, resulting in permanent utilization.	2
Arguments against CCUS		
Code	Definition	Frequency
Still emissions	Participant describes that there could be still emissions when using the CO2 in certain ways for CCUS.	4
CCUS no business case	Participant describes that there is currently no business case for CCUS	2
No stimulant for U	Participant describes that there is	1

	currently no financial stimulant from the government to use the CO_2.	
Storage location		
Code	Definition	Frequency
Offshore	Participant describes that the only option for storage in the Netherlands is offshore.	3
Infrastructure	Participant describes that the existing infrastructure is important when looking at the ideal place for storage.	1
Place attachment	Participant describes that people have a certain feeling attached to a place, resulting in less NIMBY in a place with a lot of industry	1
Other		
Code	Definition	Frequency
Difference per country	Participant describes that the public acceptance for CCS differs per country.	7

CC stays the same	Participant describes that there is no difference in the carbon capture part between CCS and CCUS	5
Convince middle ground	Participant describes that the goal of lobbying for CC(U)S is to convince the people that do not have an opinion formed about CC(U)S.	2
Different opinion	Participant describes that it matters what the CO_2 is used for, when one is forming an opinion about CCUS.	2
Not one solution	Participant describes that CCS is not a solution on itself, but can help meeting the climate goals.	2
Different arguments per country	Participant describes that the arguments that form an opinion about CCS differ per country.	1
Framing	Participant describes that the framing of a message matters when one is forming an opinion about CC(U)S.	1
More knowledge is not more acceptance	Participant describes that more knowledge about CCS, does	1

	not necessarily mean more acceptance.	
NIMBY is oversimplified	Participant describes that the not in my backyard effect is an oversimplified explanation for the public acceptance problem regarding CCS.	1
No protests	Participant describes that the most one can ask for regarding public acceptance, is that people do not protest the project.	1
Other problems	Participant describes that people in other countries have other problems than worrying about CCS, resulting in less protests.	1
Requires support	Participant describes that a measure requires support from the public.	1
SDE++	Participant describes that the SDE++ subsidy from the Dutch government bridged the gap in the business case for CCS.	1

Source of CO_2 matters	Participant describes that the source of CO_2 could matter for the public opinion about CCS.	1
Wide range of opinions	Participant describes that there is a wide range of opinions within the public about CCS.	1