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Challenges and risks related to the implementation of Carbon Capture Initiatives: the case of the port of Rotterdam

By

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Abstract

The rapid change in global climate has been a major focus of environmentalists around the world over the last few years. Carbon capture and storage (CCS) offers the technology to reduce greenhouse gas emissions, with a potential contribution of up to 17% of the required climate change targets in the COP21 Paris Agreement. CCS is categorised to be a costly technology and considered to be a new subject as there are only a few industries that have succeeded on realising the CCS infrastructure.

The Port of Rotterdam recognises the need to reduce the high amount of CO2 emissions in their industrial area and considers the development of a CCS infrastructure. However, it is highly important to examine the risks and challenges related to such projects, and the impact on the competitiveness of the port.

Following the research in this study, the current potential impact of the CCS infrastructure influences the attractiveness of the Port of Rotterdam, rather than the competitiveness. There is negative impact to the attractiveness of the Port of Rotterdam because there is currently no incentive for companies to participate in CCS. Unless the climate policy is adjusted, the adoption of CCS will remain unfavourable. However, for the long term, it is possible that the Port of Rotterdam becomes more attractive because it will already have the infrastructure in place by the time the climate policy is adjusted. Interviewees believe that as long as the infrastructure is economically feasible, the competitiveness of industrial area of the Port of Rotterdam will attract companies to invest and increase the competitiveness of the Port of Rotterdam.

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List of abbreviations

CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CSR	Corporate Social Responsibility
GHG	Greenhouse Gases
PoR	Port of Rotterdam
PA	Port Authority
ROAD	Rotterdam Capture and Storage Demonstration Project (in Dutch: *Rotterdam Opslag en Afvang Demonstratieproject*)
UNCTAD	United Nation Conference on Trade and Development
UNFCC	United Nations Framework Convention on Climate

Chapter 1. Introduction

1.1. Background

The rapid change in global climate has been a major focus of environmentalists around the world over the last few years. As part of a global action to mitigate climate change, in Paris during December 2015, the United Nations Framework Convention on Climate Change (UNFCCC) has finalized an agreement of Conference of the Parties, also known as the COP21 Paris Agreement, which was adopted by 195 countries (European Commission, 2016; UNCTAD, 2015). This agreement states that all participating countries would commit to reducing greenhouse gas (GHG) emissions and contributing to limit the average global temperature rise to well below 2 degrees Celsius by 2050 (UNCTAD, 2015).

Society has turned its attention to the negative impact of commercial, manufacturing, and industrial activities that have led to a sharp increase in the carbon footprint (Rugman & Verbeke, 1998). Due to these phenomena, many businesses around the world are under pressure to take appropriate actions in order to reduce their carbon footprint.

As the gateway to hinterland areas, ports, especially those with industrial clusters, have become aware of the need to reduce their carbon footprint. Ports around the world are giving their attention to reducing their carbon footprint without disrupting their business, or even while increasing and expanding their businesses due to the higher demand for port activities in the globalised world.

1.1.1. Carbon Capture Initiative

The Port of Rotterdam (PoR), a major industrial cluster connected to Europe's largest port, recognizes the need to set the target of reducing CO_2 emissions. They declared their CO_2 reduction target in Port Vision 2030, whereby they are using the technology of Carbon Capture and Storage (CCS) in the Rotterdam Capture and Storage Demonstration Project, more commonly known as the ROAD Project (in Dutch: *Rotterdam Opslag en Afvang Demonstratieproject*).

Vision and mission of the ROAD Project:

- Vision: "*In transition to a sustainable energy supply we will have to rely on various transition technologies in order to secure a reliable, efficient and clean energy supply*."
- Mission: "*Demonstrating that a large-scale, integrated CCS-chain (offshore) can be applied in a reliable and efficient way within 10 years (2020) and can make a substantial contribution to the climate change objectives, and share knowledge and experiences with other industries and countries.*"

Source: (Buysse & Fonteijn, 2012)

Based on research of the Wuppertal Institute, the Port of Rotterdam has described four scenarios for a transition to decarbonise Rotterdam's industrial cluster, and reduce its carbon footprint by up to 98% while still being competitive. Of the four scenarios, three of them involve the construction of a carbon capture infrastructure.

Until June 2017, the port of Rotterdam was still involved in actualising the Carbon Capture initiative through a project called “ROAD Project”. This project is a joint venture between Uniper Benelux and ENGIE Energie Nederland. Mainly, the focus of the project is to use technology named Carbon Capture and Storage, and Carbon Capture and Utilisation, commonly abbreviated as CCUS, with which the CO_2 emissions from petrochemical refineries is captured and stored in depleted oil and gas storage facilities in the North Sea.

1.1.2. Competitiveness of the Port of Rotterdam

In line with global climate change policy, CCS is bound to play an important role in reducing the carbon footprint. Given PoR’s geographical and clustering competitive advantage, PoR aims at becoming the most successful, with the lowest costs and most efficient port in terms of the CCUS implementation. In the long run, the promising benefit of having CCS encompasses the possibility of a major incentive for PoR to realise the project.

In addition, the existence of the infrastructure will help achieve the port’s objective to reduce its carbon footprint, leading to a greener and more sustainable business, and therefore increase the port’s competitiveness. As part of the dynamic maritime business, port competitiveness is a significant measure of growth in competencies and capabilities (Van der Lugt, et al., 2007). Competition between port clusters influences the attractiveness of a port to attract investments to the area based on the related business function (Van der Sluijs, 2007).

1.2. Research Objective

The main research question is "*What are the main challenges to implement Carbon Capture Initiatives in the port of Rotterdam?*”

In order to obtain answers to the main research question, there are several sub-research questions that need to be answered, which are:

1. What actions and plans have similar ports made to mitigate global climate change?
2. What are the main lessons from existing Carbon Capture Initiatives?
3. What are the success factors of Carbon Capture Initiatives?
4. What are the competitive advantages of PoR in realising Carbon Capture Initiatives?
5. What are the roles of the (main) stakeholders in a Carbon Capture Initiative?
6. What are the main risks of a Carbon Capture Initiative?

The objective of this research is to obtain an understanding of a practical orientation towards the CCS initiative. This case study is done by desk research and direct interviews with related persons.

1.3. Research Methodology

The method of research is a case study of the Port of Rotterdam. As the objective of the research is to conduct practice-oriented research, we dive into searching the literature on the topic from company websites and related news items, identifying problems and solutions by desk research and interview sessions, and also having discussions with the actors to identify more deeply the underlying knowledge about

the actions. A more detailed description of the methodology of the thesis is provided below.

(1) *Exploration*

The exploration part consists of the description of five carbon capture projects and the environmental strategies of five industrial ports around the world, which was obtained by a combination of desk research, interviews and direct contact with companies for further details. The exploration also consists of the summary of lessons learnt and a comparison of the five industrial ports in their activities relating to global climate change mitigation.

The first step is to identify and describe five carbon capture and storage projects and five industrial-clustered ports around the world. We focus on projects and ports with cases similar to that of the Port of Rotterdam. Second, we identify what are their objectives towards global climate change mitigation. For the carbon capture projects, we identify what lessons can be learned from them. Third, we describe initiatives or projects that have been or will be conducted by the five industrial ports to mitigate global climate change, especially in overcoming CO_2 emissions from their industrial cluster. Fourth is about identifying the status of such activities, whether they are implemented or not, and what is the cause if they are not yet implemented or have even been cancelled. The table indicates the date or year when the activities or projects were first mentioned and whether or not the activities or projects were success (i.e. ones that are already effective). The last step is to make a comparison table and to draw a conclusion from it.

(2) *Descriptive*

In order to analyse the background of the problem, the author needs to dig deeply into theories. Briefly, the topics that we discuss are the importance of global climate mitigation actions, available research worldwide on CCS projects, literature on port clusters, port competitiveness, port environmental strategy, sustainability in ports, green port analysis, and the role of stakeholders.

(3) *Case study*

The thesis focuses on case studies involving strategy. We realise that the topic is quite broad and complex; not much research has been specifically undertaken on this topic, as it is a relatively new innovative project. To answer the main research question, which is about the “what” and “why” context, we need a valid research on strategy, which was obtained by conducting interviews with experts, including stakeholders and people from PoR.

1.4. Thesis Structure

The remainder of this study is organised as follows.

Chapter 2 – Literature Review

This chapter provides the theoretical background of the study in the form of a literature review. The literature review is divided into the following main topics: global climate change, port strategic management in environmental issues, port strategy in corporate social responsibility, how ports respond to global warming, role of port clusters, carbon capture initiative, port competitiveness, and the role of stakeholders.

Chapter 3 – CCS Projects and Industrial Ports Around the World
This chapter presents the lessons learnt from five successful and unsuccessful carbon capture projects around the world and the environmental strategies of five industrial seaports around the world.

Chapter 4 – Case Study of the Carbon Capture Initiative in the Port of Rotterdam
This chapter discusses the case study of the carbon capture initiative in PoR. In this section, we identify the impact of the CCS initiative to the Port of Rotterdam, the risks, challenges, success factors, and benefits

Chapter 5 – Conclusion
First, this section presents the main findings of this study, whereby the answers to the research questions are summarised. Moreover, the limitations of the research are described as well as recommendations for further research.

1.5. Relevance of the topic

This study is relevant for the following reasons.

a. The actions of ports within the context of climate mitigation are relevant in an international scale. Discussing the role of stakeholders in more detail is, therefore, crucial.
b. As globalisation is one of the drivers of the maritime industry, ports will have to grow and expand in every way possible in order to remain competent and competitive among their competitors. Developing and implementing a relevant strategy in a port is critical if they are to thrive in a competitive environment. Therefore, it is important to explore the risks and challenges of the CCS project to the port. This study provides insights from people who are involved in the project and triangulates these insights with the literature.

Chapter 2. Literature Review

2.1. Global climate change

The industry of seaports is prone to the impacts of global climate change, such as the increasing sea level-rise, storms and flooding. Due to climate change, it requires adaptation strategies for the seaport industries, including coastal infrastructure (Becker, et al., 2012). As discussed by Becker, et al. (2012),

> *"Climate change will disproportionately affect ports and port-based economies, depending on their geographic location and the adaptive capacities of the ports themselves and the communities in which they are located."*

Earlier studies on climate change focused more on the physical occurrence and the possible impacts on environment. Whereas in present, more perspective of climate change is observed. Many studies nowadays have looked into environmental impacts of global climate change, specifically in agriculture and industrial sector, mainly because of the advancement in technology (Alley, et al., 1999). Some researches has also analysed the impact on human system in specific kinds of environments (Gall, et al., 1992).

For the reasons of the negative effect of global climate change, seaports need to take necessary actions. According to De Langen (2017), the activities in seaport may have negative externalities that may be harmful for the environment, such as:

- Noise effects for local residents
- Polluting the air quality of the port surrounding
- Carbon emissions of activities in the port area and/or shipping activities
- Waste generation in ports and/or resulting from shipping activities
- Damage to environment through port development

Port activities, especially the ones with industrial clusters, have a significant environmental impact (Dooms, et al., 2013). There has been several researches done to view the reaction of seaports towards global climate change.

The study by Becker, et al (2012) assesses the reactions of port administrators in the port authorities towards the impact of climate change to their operations. The study was done by conducting surveys to 342 port authorities around the world, which received 93 respondents. The results show that respondents were concerned that the physical impact of climate change on the sea would damage their operations. Therefore, policy makers on every level, insurance providers and Non-Governmental Organizations (NGOs) share information and collaborate in creating better port development system.

In addition to this, according to Burnson (2016), underlined the importance of supply chain resilience. As consumers are becoming more aware of the environmental condition, they demand transparency from companies on the climate change impacts on their products and services. Investors are increasing pressure on their business reports to provide transparency. The

study emphasizes the importance of collaborating in developing a management strategy at a global level.

Another research by Becker, et al (2013) looks into another perspective of strategic role of the players in the port, mainly focusing on the change to more global planning, investment and operation. They concluded that several ports around the world are still unaware of the actual potential threats of climate change, therefore slow to act. Ports must adapt their infrastructure to environmental conditions, collaborating with both public and private sectors due to expensive investments. However, currently it is still unclear of what adaptation strategies that is suitable for different types of ports.

Moreover, there has also been researches with the purpose to investigate the role of sea ports in the maritime transport chain (Gibbs, et al., 2014). The paper by Gibbs, et al. (2014) focuses the study on UK ports, but in an international scope of application. Their study has concluded that ships generate emissions during their voyages between ports, and that their impact is greater than any other port activities. Mostly ports would focus their efforts on reducing shipping emissions.

2.2. Port strategy in corporate social responsibility (CSR)

CSR activities within firms and businesses goes in various fields, which includes educational support, donations, ecological concerns, and investing in CSR advertisements (Okada, 2011). A research by Carroll and Shabana (2010) presents that the existence of CSR activities affects ethical responsibilities, such as environmental issues of reducing footprint, social issues relating to workforce diversity, governance issues, and relations with shareholders.

A study by Maon, et al (2010) investigates organisational implications based on conceptualisation of CSR. The demand of socio-economic responsibilities has increased the concern of CSR within the modern business activities. By viewing CSR from a stakeholder point of view, the research shows that the moral obligation represented by CSR is in voluntary language and with social responsiveness. CSR-related values must be incorporated within the management philosophy and into the culture of the organisational itself.

Moreover, Reinhardt et al (2008) looked into how firms should decide upon taking risks to consider the interest of society, which appears to be beyond environmental scope. The act of taking risks by sacrificing profits on sustainable basis can only be done if the conditions are economically feasible. These different conditions can be put into 3 categories:

(1) Voluntary CSR
The first condition is when stakeholders are voluntarily sacrificing their profits. This condition depends on the willingness of the investor to fund CSR activities. If they are, firms can start participating as well. However, voluntary CSR still allows investors to earn returns, depending on the firm itself.

(2) Reluctant CSR
On most event, corporate decisions by individual managers and directors are often profit-minded. Investors may be forced to accept as the result of external events. This condition allows the level of profits the managers can spend against investors, depending on the managers' organisational structure.

(3) Unsustainable CSR
Under certain conditions, firms that invest on CSR activities may have to increase prices and accept economic consequences. In the long term, the firm may face serious consequences that may lead the inefficient firms to disappear, or in other words, unsustainable.

To evaluate firms participating in CSR, we should see their compliance with the regulations or in costly activities. Reinhardt et al (2008) *mentions 5 sources of evidence: "voluntary government programs, voluntary industry initiatives, voluntary action by individual firms, corporate charitable donations, and shareholder resolutions".*

The case with developing countries are different from those in industrialised countries. Legal and contractual system operate poorly in developing countries. Also, environmental regulations in developing economy regions are often not as well enforced as in developed areas, which suggests that CSR could lead to benefits in net social welfare. Hence, support from strong investors are highly desirable in developing countries (Marinov & Heiman, 1998).

As the increasing effect of global climate change, more focus has been put on ecological issues. Environmentally sustainable management, which was introduced by Lun (2011) as 'green management' has gained more attention. Customers and suppliers are demanding services with minimum impact to the environment. More companies and ports are allocating more effort into shaping their CSR strategies. Especially for port authorities, they are required to respond to environmental pressure (Acciaro, et al., 2014). Some academic literature has pointed out the importance of CSR following environmental issues and touched upon measurement on the environmental impact caused by various port activities.

As pointed out by Bateman (1996), an increasing attention has been put towards the laws and regulations within the maritime industry to support the whole marine policy and sustainable development. Ports activities are a potential cause of environmental damage. Moreover, a study by Liao, et al (2010) analysed the environmental impact from certain port activities. The paper discusses the measurement to estimate carbon dioxide emissions in container transport under an empirical study. The results show an understanding to reach carbon emissions reduction strategies in route selection and more importantly, basis for evaluation of port investment projects.

A study by Acciaro, et al (2014) investigated the concept of energy management in the case of 2 ports: the port of Genoa and the port of Hamburg. The study concludes that none of the ports within the study sees energy management as a beneficial source of future revenue. Even though ports are increasingly under pressure to reduce environmental footprint, these ports response more on societal and regulation pressure.

2.3. Port development

According to De Langen (2017), the following are the several factors for a successful port development:

(1) The port community earns the 'leadership status', which needs to be developed carefully. Such status allows the port community to take initiatives

and risks. However, it is important to avoid being dominant, as dominators are focused on capturing value, instead of creating value. In addition, it is also important to differ between leadership and authority. Leadership needs to be earned, whilst authority comes from dominance. Port authority cannot succeed in the development with only dominance.

(2) Deep understanding in relevant industries. The understanding needs to be beyond recognising current trends such as ship sizes, and rather focusing on the strategic relation with major players in the relevant supply chain.

(3) Business development in ports requires great team effort and risk taking. Therefore, the organisational structure and culture needs to consists of teams that are capable of necessary risk taking attitude. Most organisations, especially government owned, are more likely to be more risk averse, which implies that the business development is less likely to succeed.

(4) The business must be able to hold on to a long term view, especially when the business opportunity is only viable for the long term and may face some delays. The decision in the earlier time will have a long term impact. The vision of the port development must be considered for a long period of time.

(5) Gaining support from the stakeholders for port development initiatives. Regional and national government are generally involved in port, mainly for their role in economical and external effects. Support from the government is often needed as well for subsidies or funding.

Globally, a number of actors in the port are taking a part in port sustainable development issues, including stakeholders and the port authority itself. According to Brundtland Commision, sustainability is described as "*the development that meets the needs of the present without compromising the ability of future generations to meet their needs*".

Moreover, according to AAPA (2007), port sustainability is defined as "*business strategies and activities that meet the current and future needs of the port and its stakeholders, while protecting and sustaining human and natural resources".* UNCTAD (2015) discusses the concept of port sustainability includes three aspects:

(1) economic perspective, which includes the cost of adaptation of port, public funding for transport infrastructure, energy prices volatility, returns on investment, and profit maximisation;

(2) environmental perspective, which includes emission reduction, noise pollution, ocean water quality, air quality, and dredging activities; and

(3) societal aspect, which includes safety of employees or general public, preventing dangerous goods in or out of the port, and reliability at optimum port performance.

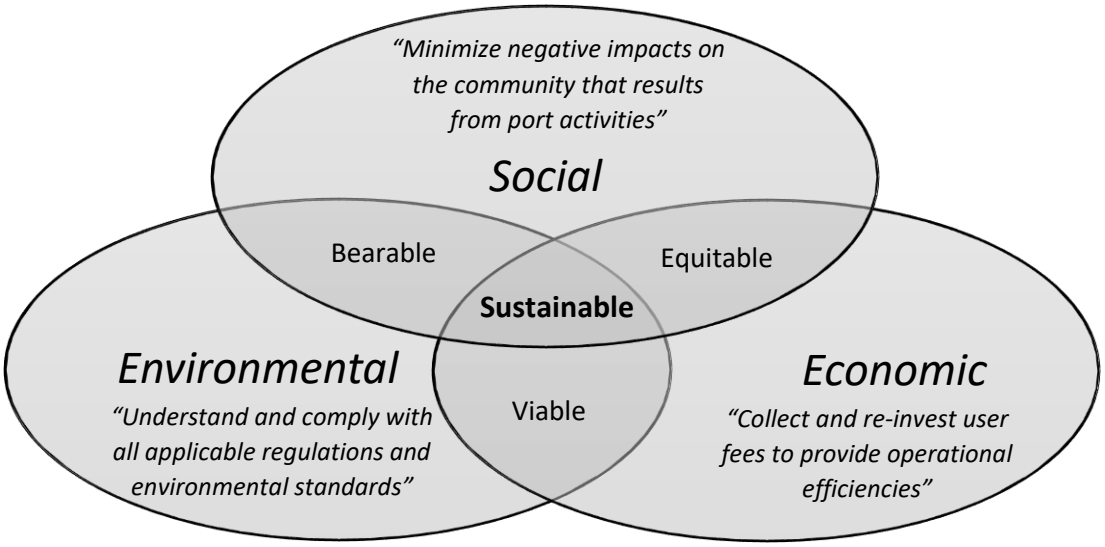

Figure 1 Triple bottom line for ports

Source: elaborated by author based on Blume (2009)

Port's sustainability performance differs between ports even though using a universal framework (Goldman, 2007). Figure 1 shows the structured framework of port sustainability. Such framework may be implemented to create basic concepts and determine the port's performance. According to Covil (2012), the environment dimension includes aquatic environment, potable water, air and atmosphere, energy, solid waste, and natural environment and soils. For the economics dimension includes business model, business management, assets sustainability, financial performance, transport chain, and regional economic impacts. And social dimension includes location and connectivity, stakeholders, corporate social responsibility, labour and education, culture and identity, and attractive and liveable waterfront.

Following this trend, there has been an increasing variety of academic studies in port sustainable development that focuses on environmental protection (Hiranandani, 2014; Davarzani, et al., 2016; Lam & Notteboom, 2014), sustainability of supply chain (Lu, et al., 2016), and economic aspect (Sislian, et al., 2016).

2.4. Port clusters

Earlier literatures have neglected the role economic geography in standard economic analysis. However, Krugman (1991) presented that economic geography holds a prominent role, especially in the global world. To analyse economies of scale, firms minimize their transport costs by adjusting their manufacturing firms within the closest range of high demand regions. However, the case is not always easily adaptable. Firms need to consider also that the location of manufacturing distributions are located nearby. For this reason, some regions tend to develop faster as the result of densely populated areas. Krugman (1991) discusses the reason for regional divergence. The following are three main reasons for industry localisation:

(1) A cluster of several firms provides a group of working with specific skills. This gives the workers an advantage because it lowers the possibility of unemployment. The industry gain benefit as well, because there's lower possibility of labour shortage.
(2) There's more support to the production of non-tradable specialised products resulting from localised industries.
(3) Industrial clustering offers abundant knowledge spill-overs which gives firms better production function than isolated producers.

Study by De Langen (2017) supports the idea of industrial localisation. There are side effects of clustering in ports, such as the spill-over effects. De Langen (2017) differs between spill-over effects in the cluster and in the value chain, which is differed geographically. The study suggests that the role of leader firms in a cluster might contribute to the performance of a cluster because of the spill-over effects.

In addition to Krugman's idea on economic geography, Malmberg, et al (1996) addresses the phenomena of spatial clustering and analyses the connection with accumulation of knowledge and firm's competitiveness. The research shows that by clustering, firms are exposed to knowledge spill over between corporations. After reviewing the theories of agglomeration, Malmberg, et al (1996) draws 2 conclusions:

(1) it is important to differ between reasons of having uneven spread of regional development and reasons of related firms and industries to locate themselves nearby
(2) the effects of knowledge accumulation is more important in understanding the reasons of spatial clustering, than the benefit of lower transaction costs.

De Langen (2017) discusses the role of port clusters association, which enables the coordination between companies in the port. The association consists of firms with similar or related industries that would work together to organise collective goods for the members. In the level of a port, such association would provide added value to the surrounding. To reach the effective regimes for the port development, the action is taken by relevant actors in the port clusters, in which all have the same aim to improve and support a specific collective good. The actors include the port authority, port cluster, firms, and public organisations, such as NGOs. The understanding of the collaboration within port clusters relates to the investments in ports.

2.5. Carbon Capture and Storage (CCS)

Following the concerns of global climate change, there have been researches on how to reduce greenhouse gas (GHG) emissions despite nowadays technology advancement and the increase of demand in technology innovations. For instance, an analysis done by Choptiany and Pelot (2014) on risk assessment model using MCDA approach for CCS decisions, by using storage locations and different mitigation actions. Their research is based on data derived from published articles and public available sources, allowing them to understand project risks and tradeoffs between complicated energy decisions. By using model that aimed at high-level CCS decisions, they use important characteristics of CCS as the criteria to the assessment, which includes environmental, social, economic, and engineering aspects. They see CCS as a unique technology because it is complex, rapidly developing, takes a long time to develop, have various impacts on different perspectives, and involves various

stakeholders. The results of their model shows the benefits of CCS and can be used as a comparative study. The model gives a transparent insight to help decision makers decide on CCS technology.

2.5.1. Overview of carbon capture initiative

As stated by Global Carbon Capture and Storage Institute (2016), CCS is a process where carbon dioxide gas emissions from industrial facilities, such as refineries and power plants, are captured and stored permanently underground. The capturing includes separation of CO2 from other gases, transport includes process of compression and transportation mostly through pipelines, and storage where CO2 is injected deep underground rock formations at depths approximately 2 kilometres or more (Global CCS Institute, 2016). It is also important to cover the importance of CCS and CCU implementation. According to Shell (2014), CCS has the potential to contribute as much as 17% of the required climate change mitigation by 2050. Fighting global climate change would be 40% cheaper if using the CCS technology, compared to without CCS.

After deliberate review on previous successful CCS projects, the Global CCS Institute (2013) explores three important success factors in related to technical issues, which are:

1. Product diversification that would improve the financial aspect of the project. Due to the condition of high CO2 price, this factor is important particularly for high CO2 capture cost industries.
2. Improved access to debt funding, which could be achieved through building alliances and creating agreements (contracts) to bridge the funding gaps.
3. The predictability and consistency of government support, followed by supporting policies. This factor is highly important for all CCS projects because the planning development for the whole CCS chain takes years even in the testing phase.

2.5.2. Perception of carbon capture initiative

The implementation of carbon capture activities depends highly on societal support. Many researches emphasized the importance of social acceptance in the CCS implementation. Researchers have looked into the perception of CCS in various perspective.

A research related to the acceptance of technology innovations, in which Huijts, et al (2007) presented the acceptance framework to create a better understanding by structuring various results. By comparing the views of professional actors, including the government, the industry, and the NGOs, and the citizens' perception, the findings of the research is that the reason there are differences in the responses to CCS is due to different attitude formation processes, which is well explained by the difference of their knowledge. People with less knowledge, who are mostly the general public, have less desire on technology innovations. That is the reason why it is important to build trust between general public and the industry or organisation. The results of the survey also suggest that environmental NGOs are trusted more than the industry and the government.

Other researches also looked into public perception towards CCS. A research by Ashworth, et al (2014) explored an understanding on how Victorians perceive and accept the potential CCS projects. The results suggest that the perception of CCS is

highly influenced by subjective norms and trust in the information source of delivering the knowledge and message. Most of the participants responded positively to the discussion of the CCS and energy technologies more broadly.

In addition, there are a number of academic literatures that looked into stakeholder's perception towards CCS, and compared the public's perception. Shackley, et al (2007) conducted a survey on European energy stakeholders, which includes industry, government, environmental NGOs, researchers and academicians. The results suggest that environmental NGOs are not as enthusiastic as the energy industry about the CCS. Environmental NGOs are concerned about the uncertain potential risk to the environment, health, and safety from the CCS technology. Most of the NGOs from the survey are pessimistic about the sustainability of the technology. The energy industry is the most confident about the role of CCS.

Van Alphen, et al (2007) emphasizes the importance of public perception for the actual implementation of CCS. The research analyses the acceptance of CCS by stakeholders in the Netherlands and the determinant of the public perception through Dutch press portrayals of CCS. The results show that the stakeholders (industry, government, and environmental NGOs) respond to CCS in a positive attitude. The public perception is to some extent similar to how the stakeholders respond towards CCS. This link however would affect if any negative aspects of CCS is introduced by the stakeholders.

As introduced by Huijts (2012), attitude towards sustainable energy technology is influenced by perceived costs, risks and benefits, and awareness of adverse consequences. The stakeholder analysis from a study by Van Alphen, et al. (2007) shows that the attitude towards CCS technologies in the Netherlands is positive. Organisations, which are mostly NGOs, see CCS as an effective solution, but still not as the first choice. This is caused by their concern on the safety for both the environment and general public, and financially acceptable.

A research by Dowd, et al (2014) aims to understanding the link between knowledge of CO2 and the perception of CCS. The earlier attempts on understanding public's response to CCS as mitigation plan was introduced by Wallquist, et al (2010). The key of the implementation of CCS is the public perception towards the benefit and the risks. With a sample from three countries (Australia, the Netherlands, and Japan), the results suggest that the misperception on CO2 links directly to the misunderstanding on CCS implementation.

As the CCS storage fields may be located onshore or offshore, the perception of CCS becomes more prominent to the implementation. Terwel and Daamen (2012) mentions the concept of NIMBY of "not in my backyard", in which people react negatively on a proposed activity that they have to support if it were located somewhere else. This study examines if this concept can be avoided at an earlier stage when the location of the CO2 storage is communicated to the public. Furthermore, this study differs between the attitude people who live in the location and people who do not. After obtaining all the main findings, the study concludes that knowledge about proposed CCS projects within a certain location should be focused to increase public trust, decreasing perception on risks, and more on spreading the benefits of the CCS.

2.6. Links between environmental strategies and competitiveness

2.6.1. Definition of port competition

One of the most powerful ways to thrive in the global market is to stay competitive among other companies. However, the well-defined method to be competitive remains a mystery to many companies. Some scholars have looked into discussing that competitiveness of a company is a relative concept compared to their competitors (Woodall, 2003; LeBlanc & Nguyen, 1999).

Woodall (2003) did the exploration of the definition of customer's value through systematic literature review, which led to an understanding of a company's competitiveness. The author explains that the company's competitiveness is relative to the competitive environment, which in this case is their competitors in the market. A research examines the concept of service value among business college students (LeBlanc & Nguyen, 1999). The author mentioned the importance key element of the positioning of an organisation in order to stay competitive among their peers. The competitive environment requires firms to offer added-value services which is the main driver of the firm's competitiveness.

A well sustained competitive advantage has been a highlight in most strategic management to survive in global competition. Several studies have discussed that competitiveness of a company is gained by formulating a good strategy, which needs to be better than their competitors (Barney, 1991; Grant, 1991; Porter 1980).

It is not a surprise that nowadays, competition among ports and hinterlands are becoming much more contestable. The study done by Notteboom, et al. (2009) reviews the uneven activities in different geographic positions. The authors look into two port research areas where New Economic Geography can be applied even with various activities in different port areas. The study is done through case studies on each of the ports. They concluded on the importance of the interaction between port competition and coordination within the port players.

2.6.2. Drivers of port competitiveness

In addition, academic studies on port competitiveness so far focused on the drivers of port competitiveness, along with their measurement. In maritime industry, ports are considered to be dynamic, in terms of the change in their business network. A study by Van der Lugt, et al (2007) reviews the global value proposition, which is highly affected by on the port community's ability to develop resources, competencies, and their capabilities.

Several studies have defined ports as one entity in which the success of their overall business depends to the whole system's competitiveness. The research by Bichou & Gray (2005) examines the terminology for classifying ports, discussing if ports should be separate markets and distinct operational and business ventures. The aim of the research is to fill in the unexplored areas in the academic research, specifically in port operations and management areas. The author looks into the inter-related global markets and business with integrated logistics and supply chain flows. They

concluded that the competitiveness of the whole business system determines the port performance.

Another research (De Langen, 2004) discussed about role of seaports in a cluster perspective as well. There are two advantages of this perspective, which are that ports are able to attract a number of activities that concentrates on the seaport, and it supports the existing theories on governance in seaports. The author concludes that there is an importance in the analysis of the governance in port clusters as it supports the understanding of port performance which could be translated into port competitiveness.

Another recent research is done by Parola, et al. (2017), which argues that the competitiveness of ports and their driver us highly influenced by major changes in the maritime industry. The main findings of this research are the series of key drivers and they concluded that the economies of scale in shipping, changes in port governance, competition among ports, inter-firm networks and green sustainability changes hold an influential role in the competitiveness of ports. The research also mentions that very few scholars so far provided an in-depth interpretation in the changes of the industry, which impacts the port competitiveness through its drivers.

Numerous studies have discussed the driver and determinants of port competition and port competitiveness. Van der Sluijs (2007) identified the determinants of port competitiveness into categories as follows:

- Financial condition, related to taxes applied to the port and financial of the project itself.
- Availability of labour, related to labour quantity and productivity, daily operation, working hour flexibility, and costs.
- Knowledge infrastructure, related to education level and knowledge basis in the region. The higher experience the labours have in a certain field, the better knowledge basis it is in the region. It creates better foundation for the development within the field.
- Port policy, related to government policies, port authority intervention, and the quality of management and organisation. In this point, the involvement of port authorities and private sector is prominent to the management structure.
- Image of the port, related to technology innovation. The reputation of the port is highly relevant to attract investors.

In order to look at the competitiveness of a port, it is also important to see the port's competitive advantage. Sölvell, et al. (1992) discusses determinant factors of competitive advantage:

- Physical resources, which include the abundance, quality, accessibility, and cost of land, power resources, and other physical features. Comparison of sources with other locations can determine the total cost of production and ease of production itself.
- Human resources, which include the quality, skills and cost of labour. The culture of a region may also determine the standard working hours and work ethics. Human sources can be categorised to their role or field of expertise.

- Knowledge resources, which may result from sources such as universities, government research institutes and agencies. A region's knowledge can be categorised based on the types of disciplines.
- Capital resources, which is the financial part, including cost and capital availability. A country's capital resources affect the rate of savings of national capital markets.
- Infrastructure, including transportation system, communication system payments or funds transfer system, and health care. The infrastructure affects the attractiveness of a region as a place to invest.

On the basis of the literature reviewed above, there are the main drivers of port competitiveness and competitive advantage, as illustrated in Table 1:

Table 1 Drivers of port competitiveness

Determinants of port competitiveness	
Financial condition	Taxes on the port; financial of the project
Labour availability	Labour quantity; labour productivity; daily operation; working hours; flexibility; labour costs
Knowledge infrastructure	Education level; knowledge basis
Port policy	Government policies; port authority intervention; quality of management and organisation
The port image	Technology innovation in the port
Determinant factors of competitive advantage	
Physical resources	Quality and accessibility to land and power resources
Human resources	Quality, skills, and cost of labour
Knowledge resources	Universities; government research institutes and agencies
Capital resources	Cost and capital availability
Infrastructure	Transportation; communication; fund transfer; health care

Source: own elaboration based on Van der Sluijs (2007) and Sölvell, et al. (1992)

2.6.3. Environmental strategies and competitiveness

Several studies provide different perspective and theories on the links between environmental policies enforced in an area and the industry's economic performance. There are three approaches in identifying these issues:

(1) The neoclassical environment economics approach reasons the environmental regulation intends to improve their performance to reduce any negative externalities, which is translated into the port's environmental strategies. However, these actions might burden companies with additional costs (Iraldo, et al., 2011). A study by Jenkins (1998) mentions that firms complying to the environmental regulations or firms affected by the environmental regulations will lose their market share because they have to spend more on production costs, which will lead to industrial sectors stop participating and relocate to regions with less strict regulations.

(2) Different to the neoclassical approach, the revisionist approach views environment performance has become a prominent factor for an industry to improve their competitive advantage. It could lead to more efficient production, increase of productivity, and new market opportunities. Industries can sell their solution and innovation to other firms as one of the advantages of "first mover"

(3) Resource-based view (RBV) is a theory that aims to view the competitive advantage as the result of the organisation's resources, such as continuous innovation and stakeholder management. With RBV it enables to study unforeseen organisational resources and capabilities, and link between environmental strategy and the performance of the organisation.

All of these approaches is useful for understanding how environmental policies influence an industry's economic performance, including the competitiveness. It also helps understanding under what condition the relation happens. Besides assessing the impact of policies, it is also possible to assess new innovation (Iraldo, et al., 2011).

2.7. Stakeholders in port cluster

Freeman (1984) described stakeholder as "any group or individual who is affected by or can affect the achievement of an organization's objectives". Each of these actors interact and may have different interests and own different resources of influence. Therefore, analysing causes of action within a port cluster may be complicated as there are conflicting interest among different stakeholders (Heaver, 1995). Figure 2 illustrates the stakeholders in a firm.

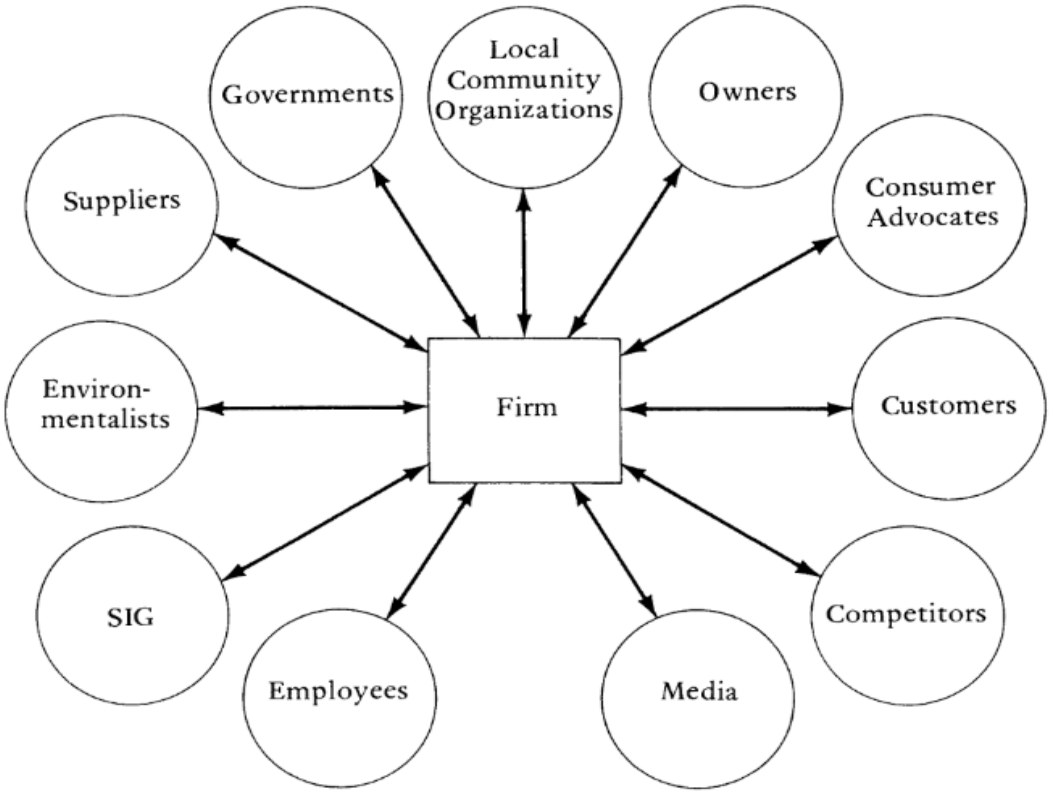

Figure 2 Stakeholder at a firm

Source: Freeman (1984)

De Langen (2006) introduced a detailed explanation on important stakeholders of seaport clusters, which is in line with the definition of stakeholders by Freeman (1984):

- Transport firms, who are pressured to have lower cost due to taxes, emission standards, and security regulations, to improve their competition position

within other transport providers in other areas. Therefore, these firms would attempt lobbying for transport friendly policies.

- Port labour, includes all workers in the port area, such as port administration and for companies providing services. For these workers, they are interested in high wages, career opportunities and job security. The port labours would influence the ports through port strikes and having impact on image of working in seaports.
- Port-related manufacturing industries are companies that are located in the port area, such as shipyards and offshore activities. These type of companies are interested in the attractiveness of the location of the seaport for the manufacturing activities.
- End users of ports whose interests are to have low generalised transport costs. Having end users of ports would improve agglomeration economies which requires a large supplier and the customer. The role of end users of ports is the attempt to influence related actors through branch associations or diverting cargo to other ports.
- Local environmental groups that focuses on regulations preventing negative externalities. Their actions include of using procedures to postpone or avoid any investments that would lead to negative externalities.
- Local residents, whose interests are for the job creation, limited traffic congestion, and their quality of life to remain the same or improved due to the port activities. They can affect through political pressure.
- Local and regional government who concern on the contribution to regional economy, regional tax income, and to have effective transformation of the port-city interface. They would improve the performance through regional planning and public investments in ports.
- National government, who is interested in having low generalised port costs for residents and firms, and to have cost recovery of infrastructure. The national government's role is to have national investments in ports and to create port laws. Most importantly, they are the national role in infrastructure planning.

Haezendonck (2001) classified the stakeholders involved in seaport competition into 4 categories:

(1) Government organisations, at national, regional and local levels.
(2) The port authority
(3) The port companies, which are commonly private owned bodies. The port companies involved can be distinguished into 2 sub-categories, which are the port operators, who are directly engaged to the port's logistics chain activities and companies involved in port related activities, such as manufacturing firms within the port area.
(4) Port customers, which would be concerned as the demand side.

According to De Langen (2017), ports are facing a challenge to protect stakeholders' interest for port development. Port development companies are obliged to create long term plan to be agreed by national governments. Port planning must take into account different interests of various stakeholders (Dooms, et al., 2004). However, the pressure between protecting the environment and port development is increasing and becoming more visible in every port (De Langen, 2006). This issue is being more frequently mentioned in reports of port authorities, especially due to global climate.

Van Alphen, et al. (2007) defined stakeholders in a CCS projects as "*agents with a professional interest in CCS*". A study by Shackley, et al. (2007) suggests that European energy stakeholders is defined as "*those with a professional interest, and/or involvement, in energy and climate policy and economics, energy technologies, climate change mitigation and so on*". Therefore, the stakeholders involved in CCS projects consist of industry, non-governmental organisations (NGOs), governments, and research institutions (Van Alphen, et al., 2007; Shackley, et al., 2007).

2.8. Chapter Conclusion

The answer to the main research question "What are the main challenges to implement Carbon Capture Initiatives in the port of Rotterdam?" is complex, therefore requires the understanding of the determinant of port competitiveness as the impact of environmental strategies, determinant of a port's competitive advantage, public perspective of CCS, and success factors of CCS.

Ports which are connected with large industrial clusters have a huge impact on the environment. Ports would need to act according to the current climate change situation. Strategies within a firm, which includes activities to support ecological support, is often known as corporate social responsibility (CSR). Global climate change pressures industries with high emissions to perceive CCS as their corporate social responsibility.

The Port of Rotterdam's direct interface with the industrial cluster, CCS has become an important tool to help reduce emission. Aiming to play a role in making chains more sustainable, the Port of Rotterdam perceive CCS as one of the CSR in the energy transition scheme. Key factors to a successful CCS project are financial improvement, more access to debt funding, and the consistency of government support.

There are three important aspects to manage sustainable development of port: economic, environment, and societal aspect. As a way to understand the performance of a port, port competitiveness is influenced by various determinants, based on the business the port is competing. In this case, we need to link between environment strategies and port competitiveness. Based on the study of literatures, there are three approaches, which are the neoclassical environment economics, revisionist, and resource-based view. To determine port competitiveness, there are several aspects that are important, which are financial condition, availability of labour, knowledge infrastructure, port policy, and the image of the port.

We conclude, to assess the impact of CCS as a CSR in a port, we need to analyse the benefit of CCS to the industries in the port and the port performance, which is reflected on the port competitiveness. The factors that would influence the results are the challenges, success factors, and the competitive advantage of the port condition.

The main insights obtained from the literature section is presented in Table 2.

Table 2 Main insights from the literature review

Corporate Social Responsibility (CSR) Strategies	
Categories of CSR	Voluntary CSR; Reluctant CSR; and Unsustainable CSR
Port Development and Sustainability	
Success factors	(1) The port's "leadership status" (2) Deep understanding in relevant industries (3) Great team effort on risk taking (4) Long-term commitment (5) Stakeholders support
Perspective	(1) Economic: investment for operational efficiencies (2) Social: impacts to the community (3) Environmental: comply to environmental standards and regulations
Port Clusters	
Reasons for clustering	(1) Specific skills workers (2) Supporting non-tradable specialised products (3) Knowledge spill-overs
Carbon Capture and Storage (CCS)	
Success factors	(1) Product diversification (2) Access to funding (3) Consistency of government support
Port Competition	
Determinants of competitiveness	Financial condition, labour availability, knowledge infrastructure, port policy, and image of the port
Determinants of competitive advantage	Physical resources, human resources, knowledge resources, capital resources, and infrastructure
Approaches to review economic performance	(1) The neoclassical environment economics (2) The revisionist (3) Resource-based view (RBV)
Stakeholders in Port Cluster	
Stakeholders consists of:	Transport firms, port labour, port-related manufacturing industries, end users of ports, local environment groups, local residents, local and regional government, and national government

Source: own elaboration based on various sources

Chapter 3. CCS Projects and Industrial Ports Around the World

3.1. CCS projects around the world

The technology of CCS has been the subject of research for a long period of time. However, there are still very few CCS projects that have been successful. Some of them failed and did not lead to the desirable outcomes for various reasons. The goal of this section is to identify both similarities and differences of CCS projects around the world. The five CCS projects that have been selected in this section include two successful projects, two projects that are still ongoing (in planning phase), and one project that was cancelled. The reason behind such selection is to identify the success factors and the failure factors, which can be used as lessons learnt for the future projects.

Below we present the descriptions of five carbon capture projects from all over the world and the lessons that can be derived from them. The five selected ports are the Teesside Collective in the United Kingdom (UK), the Petra Nova in the United States, the Norway Full CCS Chain, the CO2CRC Otway in Australia, and the Barendrecht CCS Project in the Netherlands.

(1) Boundary Dam (SaskPower), Saskatchewan, Canada
Boundary Dam is a power station located close to Estevan, Saskatchewan, Canada. The power station became the first to use CCS technology in 2014, capturing up to 1.3 Mt per annum of CO2 (SaskPower, 2017).

Despite the advantage of spatial proximity to offshore storage location and high concentration of CO2 source, the Boundary Dam CCS project faces some challenges and barriers before the CCS commencement. The financial gap between costs and benefit concerns the feasibility of the project. Moreover, to reach the climate targets, the CCS infrastructure needs to have capture scale of 4 Mtpa of CO2, which is also a challenge for SaskPower. The parties involved believes that they still need deeper scientific understanding of risks of the technology. Legal and regulatory issues are also concerns with the national authorities. Furthermore, the public engagement was challenging as some people are unfamiliar of the significance of the technology (Mitrovic & Malone, 2011).

From the Boundary Dam CCS Project, it is clear that good response towards the climate, target policy support and government support is needed to have a successful CCS. Politic support is an important aspect in the implementation of CCS. Therefore, an understanding on political support is needed to know the advantage and the challenges. Moreover, since the development of CCS takes a long period of time, the parties involved need to set out long-term vision on their participation in the CCS project (Mitrovic & Malone, 2011).

(2) Petra Nova, Houston, United States

The CCS project ‘Petra Nova’ in Houston is a joint venture between the integrated US power producer NRG and Japan’s JX Nippon Oil & Gas (NRG, 2017). The project has been operational since January 2017, and it is based on a post-combustion CO2 capture system. Currently, the project is capable of capturing 1.4 Mtpa post-

combustion CO2, which is transported via 80-miles pipeline to the West Ranch oil field for enhanced oil recovery (Global CCS Institute, 2017).

As one of the first "mega-scale" CCS projects, the Petra Nova project faces a challenge of commercialisation. In order to keep using the coal power plants, emissions from coal and other fossil-fuelled power plants must be eliminated. According to Jenkins (2015), there are three main challenges faced by the Petra Nova project: (1) scale of capture systems must be increased; (2) costs must be kept to the minimum; (3) pioneering projects must be able to prove that post-combustion carbon capture and enhanced oil recovery projects are safe, reliable and profitable investments. The Petra Nova's synergies with the oil industry benefits the project, as well as the use of the existing pipeline infrastructure.

Being successful in securing government funding, there are some lessons that can be learnt from the Petra Nova project:

- Developers must be patient and highly determined to see progress of the project until its completion itself. Setting time limits on projects has proved to lead to failure in the past (Herzog, 2016). The Petra Nova project has been developed over a period of at least seven years, therefore, any company that participates in the project must be ready for the long-term commitment.
- In terms of financing, the Petra Nova project must be able to manage an original, yet complex deal with multiple partners in order to successfully execute the project.
- Government agencies should be willing to work with commercial industries for the project and mitigate any risks for the companies involved.
- It is important to have project financing by investors that are willing to take risks of such unproven technologies, investors that typically look at the potential market opportunities and are interested in economic developments and other possible impacts. In this case, two investors of the Petra Nova project, JBIC and NEXI, saw the opportunity to put Japanese companies in the frontier of the market, to secure important natural resources, and the advancement of environmentally friendly technology of Japanese firms.
- Energy technology must have a clear path to profitability. Even though companies might want to take risks, they would consider it only if they see opportunity for enough economic returns.

(3) Teesside Collective, United Kingdom

This project involves an industrial cluster of energy-intensive companies in Tees Valley, UK. Industries in the region emit carbon dioxide around 20 Mt per year, which is equivalent to 22% of total emissions in the UK (Cambridge Econometrics, 2015).

The first phase of the CCS project is planned to start in 2020. The CCS operation is designed to capture 0.8 Mt of carbon dioxide per year over the first 15 years. The captured CO2 will be transported through a pipeline to an offshore field in the North Sea as a dedicated geological storage. The Tees Valley is often referred to as one of the most suitable locations for the development of CCS chain in the UK for three reasons: (1) its accessibility to a range of offshore storage options; (2) the fact that it is a concentrated area of manufacturing plants which helps reduce costs for constructing the CCS infrastructure; and (3) it has relatively low CO2 transporting

costs. Despite the advantages, the development of the project still faces challenges such as the costs, securing financial systems, storage risks, and the long term liability of the CO2 storage (Cambridge Econometrics, 2015).

A study by Herzog (2016) describes some lessons that can be taken from the development of the Teesside Collective CCS project:

- Following the climate negotiations, the enforcement of the EU Emission Trading Scheme (ETS), which requires CO2 allowances, can be one of the incentives for reducing emissions in the EU. This situation can potentially lead to the increase of carbon price and, thereby, affect competitiveness of the industrial area.
- The commencement of CCS chain can support jobs within the area, either directly or indirectly. According to Cambridge Econometrics (2015), developing CCS network in Tees Valley can create 1,000 direct and indirect short term jobs during the construction period, and later 350 long-term jobs that would be involved in the operation and maintenance of the CCS chain.
- Other than economic benefits, as a first mover, the Teesside Collective can be used as an example for future development of CCS in the UK.
- Potential spill over effects which could lead to new technology innovations and improvements, either in the same or in different sectors of the industry.
- The project would lead to linking investment and industrial activity, which could balance the growth in the UK. The use of CCS chain could improve employment opportunities, reducing the problem of unemployment in several areas of the country.

(4) Norway Full CCS Chain

The CCS project in Norway, which is called the 'Norway Full Chain CCS' has the capability to capture 1.3 Mtpa of CO2 by 2022. The source of carbon comes from 3 production plants: ammonia production, cement production, and waste-to-energy recovery plant, which is located in the south of Norway. The storage site is in the offshore Smeaheia, and involves transporation system that allows transport between ships and pipelines (Global CCS Institute, 2017). The existing carbon tax system in Norway enables the Norway Full CCS Chain to benefit from it as an incentive for the CCS driver. However, the CCS project still face technical issues, costs, and ways to secure the financial securities (Onarheim, et al., 2015).

According to Onarheim, et al (2005), there are several lessons that can be learnt from the Norway CCS chain:

- One of the actions that the Norwegian authorities implemented to reduce greenhouse gases is implementation of tax system for CO2 emissions.
- Different types of production plants might have different technical issues. From the perspective of CCS projects in Norway, sectors that have the highest potential in CCS are oil and gas, iron and steel production, and cement production. However, national distribution of industrial sectors and availability of storage fields depends on the location.
- CCS is so far the most significant solution to mitigate global climate change. There might be other options of mitigation actions, but the effects would not be as significant as the implementation of CCS.

- There is a possibility of carbon leakage in the process of implementation. This would lead to the decrease of competitiveness of industries within the area as most of these industries compete in global markets in any additional CO2 cost burden.
- Coordination of CCS could risk to decrease competitiveness as the industries would rely on the politics of the area. There is a challenge in coordinating the CCS chains to remain competitive.

(5) Barendrecht CCS Project

The Dutch CCS Project, mostly known as Barendrecht CCS Project, is located in Barendrecht, a place close to the Rotterdam harbour area, in the West of the Netherlands. The objective of the project is to be a demonstration project for the storage of CO2. The source of the CO2 is from the hydrogen plant in Barendrecht. The planned volume of CO2 to be injected is approximately 10 million tonnes (Ashworth *et al.*, 2012).

An in-depth case study on the stakeholder management of the Barendrecht CCS project was conducted by Brunsting, et al (2011). In this study, the authors found that one of the issues of Barendrecht CCS project was the difference of beliefs, value, and perception of the stakeholders, towards the project itself. The difference in their respective roles in the project might be the reason of the found differences. These differences might influence the decision-making process. It was also pointed out in the study that one of the biggest challenges was that some of the stakeholders were not familiar with the significance of the technology, resulting in them having less neutral opinions about the CCS.

The study summarised several recommendations based on the analysis of Barendrecht CCS project (Brunsting *et al.*, 2011):

- The basic concept planning must be cleared and accepted at the earliest stage of the project. Setting up a project in a more structured way should help avoid any uncertainties afterwards.
- Stakeholders should be involved in the process as early as possible. This is to make stakeholders have the same perspective, and leads to more neutral decision making.
- Costs and benefits should be communicated to all the shareholders in a transparent manner to avoid different perspectives colliding.
- Communication between government and stakeholders must be aligned in terms of support and coordination.
- Because knowledge is an important part of the project, there should be trust between the actors before taking care of any knowledge gaps.

Table 3 Comparison of five CCS Projects

No.	*Project*	*Location*	*Scale*	*Status*	*Competitive advantage*	*Challenges*	*Lesson learnt*
1	Boundary Dam	Canada	1 Mtpa	Active since 2014	(1) Spatial proximity to offshore field (2) High concentration of CO2 source	(1) Financial gap (2) The scale of 4 Mtpa of CO2 (3) Scientific understanding of risks (4) Legal and regulatory issues; (5) Public engagement	(1) A successful CCS requires enforced climate response, supported with targeted policy and the government; (2) An understanding on political support is important to know the advantage and the challenges; (3) Parties involved need to set out long-term vision on their participation
2	Petra Nova	US	1.4 Mtpa	Active 2017	(1) Synergies with the oil industry (2) Pipeline infrastructure	(1) Costs (2) Access to funding (3) Engagement with financial institutions (4) Permitting (5) Public acceptance	(1) Companies involved be ready for long-term commitment (2) Petra Nova manages a complex deal with muliple partners to succeed the execution of the project (3) Investors of CCS project must be willing to take risks (4) Energy technology must have a clear path to profitability
3	Teesside Collective	UK	0.8 Mtpa	Planning phase	(1) Accessibility to offshore storage (2) Concentrated area of CO2 source (3) Low CO2 transporting costs (4) Using existing infrastructure	(1) Costs and financial securities (2) Storage risks (3) Long-term liability	(1) CO2 allowance from EU ETS can be in incentive; (2) CCS chain can support direct and indirect jobs in the area; (3) The project can be used for future development (4) Potential spillover effects to new innovations and improvements; and (5) More balanced investment and industrial growth in the UK
4	Norway Full CCS Chain	Norway	1.3 Mtpa	Planning phase	(1) Carbon tax system as an incentive	(1) Technical issues (2) Costs and financial securities	(1) One way to reduce GHG is with the implementation of tax system (2) Different types of production plants have different potential in CCS (3) CCS is so far the most significant

No.	*Project*	*Location*	*Scale*	*Status*	*Competitive advantage*	*Challenges*	*Lesson learnt*
							solution to mitigate global climate change (4) Firms must be aware of the possibility of carbon leakage that might affect the industries' competitiveness (5) As industries will coordinate in CCS, there might be less competition between industries because they rely on the politics of the area.
5	Barendrecht CCS	The Netherlands	10 Mt	Cancelled	(1) Concentrated source of CO2 emitters to be captured (2) Lower CO2 transport cost from the source to the onshore storage	(1) Different perception of the project's value between parties (2) Stakeholders unfamiliarity to the significance of the technology	(1) The basic concept must be clear at the early stage (2) Stakeholders should be involved as early as possible (3) Transparency of costs and benefits is important between shareholders (4) Aligned communication between government and stakeholders (5) There should be trust between all the actors before addressing to the knowledge gaps

Source: own elaboration based on various sources.

3.2. Summary of CCS Projects

There are several aspects that we can learn from existing CCS projects, including the competitive advantage, risks and challenges, and lessons learnt (Table 3). From various CCS projects, it is become clear that the accessibility and spatial proximity between the cluster to the offshore storage location can be an advantage in building CCS infrastructure. The highly concentrated source of CO2 emitters to be captured can also lower complexity in managing the CO2 transport and lower transport costs. For Teesside Collective and Petra Nova CCS Projects, the use existing infrastructure also lowers the costs. As for Norway Full CCS Chain, the existing carbon tax system provides an incentive as one of the drivers of CCS implementation.

Main challenges that are often mentioned are costs, securing financial system, and public acceptance. These three aspects are the most challenging aspects to implement CCS infrastructure. In most regions, the climate policy does not give enough incentive to allow parties to benefit from the implementation of CCS. This situation creates financial gap between expenses and the benefit. The fact that CCS is a relatively new infrastructure, most regions find that public acceptance can be one of the main challenges for the implementation. Moreover, some projects mention the importance of the alignment of perception of the project's value to avoid any misunderstandings.

After assessing the lessons learnt from previous CCS projects, it is clear that the implementation of tax system is an effective way to reduce GHG. The CO2 allowance in the climate policy can be used as an incentive to drive the use of CCS forward. In addition, as the development of CCS takes a lot of time, the parties involved must be ready for long-term commitment in the project. Moreover, the communication between parties, especially between the stakeholders and the government, must be aligned to avoid any misunderstanding.

To add together, there are several aspects that are important to be noticed from previous CCS projects:

- The role of climate policy is critical for CCS. Following the Paris Agreement, new climate policies should be put in place around the world. However, the key question that remains is whether the new policies will be sufficient to help move CCS forward. Moreover, the enforcement of EU ETS that would provide incentive for CCS can potentially be one of the main motivations to use CCS. Otherwise, there would be no incentive for companies participating in the CCS chain, unless government would participate by providing subsidies or implementing taxes.
- Communications and public outreach is critical. Public society would potentially be opposed to radical change and the use of new technologies that are beyond their knowledge and that would possibly affect their lives. Having Barendrecht CCS project as an example teaches us that despite the maturity of the project, there is still a possibility for local government to cancel the CCS project due to protests from local society. Society is concerned that there would be negative externalities from having an onshore storage within a residential area. Public outreach must be performed from an earlier stage of the project. Several studies emphasised the importance of a good public outreach. All the stakeholders - local farmers, local society, industry experts, need to be informed. Two-way communication is also important since everyone might have an opinion.

- Knowledge gaps should be taken care of to avoid any misunderstandings between the actors of the CCS project. It is important to include all the actors, including stakeholders, into the discussion at the early stage. It is important to build trust before addressing to the knowledge gaps. To do this, it is also important to have transparency between parties, especially on sharing knowledge about costs and benefit. In addition, parties may also be aware of the knowledge spill over effect on the development of CCS.
- Securing the financing system at the early stage. Several previous projects because they had governmental funding. However, since the CCS projects take years to develop, the political situation might change, thereby creating the risk of cancellation of the government support. Therefore, financial system must be secured as soon as possible.
- Basic concept must be agreed from an earlier stage to avoid confusion on the next stages. Stakeholders should also be involved as soon as possible, including on the technical aspects to build the same perception and knowledge between all parties.
- Alignment of perception between government and the stakeholders. The success of a CCS project depends on many aspects, including the stakeholder's perception and interests. Involvement of local, regional, and national government is a must throughout the whole project. It is critical to maintain the relationship between the government and the stakeholders to create the right circumstances.
- CCS chain can support jobs. The whole chain of CCS can create more job opportunities for people within the area, either direct or indirect jobs.
- The development of CCS takes a lot of time. The parties that are involved must be ready to commit and to have a longer-term vision on their participation on the project.
- It is clear that there are various types parties that are involved in CCS projects. Companies must be ready to create complex deal with various parties to make the CCS successful.
- Despite the mature development of the technical knowledge of the CCS technology, it is still important to be aware of the possibility of CO2 leakage in the storage. Therefore, it is highly important to manage the liable party to be hold responsible for the leakage risks.

3.3. Environmental strategies of industrial-clustered ports

According to the media, the top 10 global ports in 2014 are Shanghai, Singapore, Rotterdam, Ningbo-Zhoushan, South Louisiana, Santos, Hamburg, Busan, Mombasa and Felixstowe (Writer, 2014). This selection is based on the list of the world's biggest and busiest seaports. If we select ports based on the highest container throughput, the list will include such ports as Shanghai, Singapore, Shenzhen, Ningbo-Zhoushan, Hong Kong, Busan, Qingdao, Guangzhou, Jebel Ali (Dubai) and Tianjin (World Shipping Council, 2014).

Both of the selections are valid, however, both of them are irrelevant for this study. The selection appropriate for this study needs to include ports that reflect upon relevant and sufficient geographical diversity and allow for comparable environment strategy. Therefore, in the selection, it is important to consider the industrial clusters which would include the necessary environmental strategies to reduce the CO2 emissions.

To make a relevant selection of clusters, the selection has to meet the following criterias: (1) the port has to be connected to an industrial-clustered area; (2) the port has to be a global port; (3) information for the study has to be in English and possible to be obtained through desk research. Based on these requirements, the selected ports are the Port of Los Angeles, the Port of Singapore, the Port of Antwerp, the Port of New Orleans, and the Port of Rotterdam.

(1) Port of LA

Being America's number one container port, the Port of Los Angeles (PoLA) has an image to maintain. The PoLA has a number of initiatives to take part in a global scale to reduce air emissions, to improve water quality, to develop facilities and new technologies, and to provide good jobs for the society. The port has a number of sustainability programs to achieve this goal. The port's major sustainability programme includes such topics as community investment, land use and infrastructure, public health, energy and resource conservation, and financial strength (Port of Los Angeles, 2013).

- Community investment
  The community investment intends to protect shared ecological resources and to maintain the development of healthy community. Within the community investment, the port has several initiatives which include LA waterfront project, community mitigation trust fund, and community aesthetics.
- Land use and infrastructure
  The port has set a clear priority to ensure that the lands are used in the best possible way and to maintain the infrastructure for all the port's tenants. The initiatives under this programme include capital improvement program, land use planning, climate adaptation, and southern California international gateway.
- Public health
  The initiatives in the public health section are aimed to reduce health risks, by preventing air emissions, ensuring the monitoring control and its mitigation. According to Port of Los Angeles (2013), the initiatives are *"Clean Air Action Plan (CAAP), Environmental Ship Index (ESI), vessel speed reduction program, alternative maritime power, marine engine exchange program, clean truck program, rail locomotives, pacific ports clean air collaborative, climate leadership award, climate change mitigation, world ports climate initiative, and the mitigation monitoring and reporting program"*.
- Energy and resource conservation
  In terms of the maintaining efficient operations and preventing environmental degradation, the port developed several initiatives to protect water-based resources, to monitor and, to maintain healthy wildlife population, to conserve energy, to switch to renewable energy, and to promote cleaner technologies. The initiatives are Water Resources Action Plan; Tenant Stormwater Outreach Programme; California Least Tern Site Programme; Energy Management Action Plan; Renewable Energy Programme; Zero Emissions Roadmap; Technology Advancement Programme; Green Building Policy; and Waste Diversion.
- Financial strength
  The port plays an important role in the economies of the region. For this reason, it aims to strengthen financial performance by enhancing their relationship with

export partners and ensuring the employee's leadership by organising training workshops.

The PoLA does not mention the use of CCS technology within the port. However, the LA Department of Water and Power (LADWP) mentions in their opportunity to significantly lower their CO2 emissions from the coal-fired power plants by the use of CCS technology. One of the challenges for LADWP is that the technology is not yet tested or demonstrated for a commercial scale.

(2) Port of Singapore

The authority of the Port of Singapore has introduced various green programmes on different topics, from the eco-friendly practices to maintaining the culture of corporate social responsibility. The staff of the port are encouraged to promote recycling and to increase awareness of their day-to-day activities throughout the year. The port has also introduced greener devices and technologies in its operations, such as the gantry cranes and e-RTGs that run on electricity, thereby making sure that there are no carbon emissions. Apart from that, infrastructure in the port area is designed to use natural lighting, thereby reducing the use of electricity.

Being one of the busiest ports in the world, the port authority ensures environmentally-friendly port activities in the port area. The port aims to achieve more emission reduction in the maritime-related businesses such as terminal operations, ship operations and harbour craft operations. The programme's system includes providing incentives for funding of development and adoption of green technology systems.

(3) Port of New Orleans

The Port of New Orleans is located in the proximity of the refining and chemical manufacturing plants, which is ideal for the port that is used as a departure point for chemical and petrochemical exports. In the current times of globalisation, increased economic activity and fossil fuel consumption makes the port realise the importance of reducing greenhouse gas emissions. In line with its environmental policy, the port aims to protect the environment, complying with applicable laws and regulations on pollution prevention, as well as it aims to ensure safety for the employees and the community.

To comply with the environmental policy, the port has introduced the following programmes and initiatives:

- By-you drainscapes
  The aim of this programme is to maintain the relationship with the society, including residents, artists, students, authorities, and organisations in the region, to improve public awareness of drain artwork in public places. By creating eye-catching artwork, the port aims to make people interested in stormwater infrastructure and pollution prevention. The programme also intends provide new tourism object and develop community awareness (Federer, n.d.).
- Green marine environmental programme
  This programme gives opportunities for maritime companies to create strategies to reduce their environmental footprints within the given framework. There are several impact reasons to support this programme, such as environmental leadership, community impact, greenhouse gas emissions, and

abating polluting air emissions. Each company is responsible for its own emission reduction strategy and must show continuous improvement within the established levels. (Green Marine, 2014)

- Trash free waters pilot project
  The main goal of the project is to reduce trash entering the US waters. With the help of port tenants and community stakeholders, the port prevents any trash, litter and debris from entering the waterways. The project intends to support and expand port business through value added activities (AAPA Environment Committee, 2015).

(4) Port of Antwerp

The Port of Antwerp's sustainability strategies focus on people, environment, and economic activities. The focus on the environment means protect the natural environment in and around the Scheldt estuary. The port authority aims to improve the quality of water, air, and soil. In order to do that, the port provides incentives to clean vessels, as well as controls the waste flows. Companies within the port area are on the same side when it comes to reducing emissions. The Port of Antwerp categorises its strategies into three parts: vital and effective, environmental-friendly, and local support.

The newest initiative on land was the Low-Emission Zone (LEZ), introduced in February 2017. Companies are encouraged to work on sustainable port transport, including trucks and private cars. Later in 2018, the port authority will conduct a survey to see if additional measures should be implemented. Initiatives on water include construction of LNG bunker station for barges and cars, more stringent standards for sulphur content of fuels for vessels, support of Nitrogen Emission Control Area (NECA), incentives for environment-friendly vessels, onshore power supply for barges, policy for developing onshore power facilities for seagoing ships, and the greening of the port's tug and dredger vessels.

In 2011, the Port of Antwerp had plans to start the development of CCS infrastructure for the port's industrial area. The plan was to create CO2 pipeline network connected to the Port of Rotterdam. Four areas of research identified in the Port of Antwerp were the assessment of potential CCS infrastructure in the port, CO2 recycling, the economic analysis to transport CO2 to the port, and analysis of market players with role of CO2 storage. The main objective is to operate a demonstration phase in a period of five to ten years.

(5) Port of Rotterdam (PoR)

The PoR aims to maintain its sustainability, by working towards a greener industry and logistics, and by supporting the quality of the port's surroundings. Given its rapid growth, the port develops sustainable alternatives to lessen the negative externalities. The port authority (PA) classifies its CSR strategies into three categories: safe and healthy environment; climate and energy; and people and work. Several alternatives to fossil fuels within the energy transition strategy are wind energy, solar energy, and the use of biomass fuel.

Following the Netherlands' commitment to the Paris Agreement, the PA of the PoR targets to keep emissions from the port activities within the agreed limits. In doing so,

the authorities, in collaboration with the Wuppertal Institute for Climate, has put forward four decarbonisation pathways.

- Business as Usual (BAU) pathway is characterised optimising existing activities with current technologies, and a decrease in refinery activities. There will be no significant change in the future climate policy measures. This pathway provides decrease of CO2 emission, however not sufficient in achieving the agreed climate targets. The activities include the adoption of best available technologies, reinvestments in refineries and plants, water electrolysis, and small scale power to heat.
- Technological Progress (TP) pathway includes rapid implementation of available technologies and the implementation of large scale CCS. Through their implementation, the CO2 reduction is expected to decrease by 75% in 2050 (when comparing the levels of CO2 reduction in 2015).
- Biomass and CCS pathway suggests a drastic change towards the production of renewable energy and the use of large scale CCS to eliminate CO2 emissions. This pathway includes heat grid extension, CCS on power plants, 100 percent biomass use, water electrolysis, power to heat, and synthetic fuel and bio based production. This pathway may lead to an eventual 98 percent CO2 reduction.
- Closed Carbon Cycle is a pathway in which the energy system is drastically changed to renewable energy to become fully decarbonised. Activities within this pathway include the use of wind energy, power to heat and geothermal heat, heat grid extension, renewable electricity production, synthetic chemical production from waste streams, and water electrolysis. Similar to the Biomass and CCS pathway, the Closed Carbon Cycle gives a CO2 reduction of 98% by 2050, compared to the CO2 levels of 2015.

3.4. Summary of Environmental Strategies

This section summarizes the environmental strategies from international seaports around the world.

Port of Los Angeles mainly focus their development in reducing air emissions, improving water quality, and developing technologies to provide jobs for the society. Port of Singapore focus on their green programs, starting from the workers' awareness in daily activities throughout the year. Programs related to daily activities include the use of greener technology with no emissions and the use of natural lighting for the infrastructure in the port. The Port of New Orleans realise the importance of taking action in reducing their carbon emissions. The port provides a framework for maritime companies to set their own strategy to reduce carbon emissions. The Port of Antwerp also focuses on the people, environment, and their economic activities. The port organises their strategies in three categories: vital and effective, environmental-friendly, and local support. The Port of Rotterdam intends to work towards greener industry and logistics and classifies its CSR strategies into three categories: safe and healthy environment; climate and energy; and people and work.

Based on the study in five seaports, it seems clear that all of the seaports are aware of the importance take actions to reduce CO2 emissions in their ports. The actions taken for each ports differs based on the need, the ability, and the competitive advantage of the port.

Table 4 shows the comparison of each selected port's environment strategies and the ports' perception on the use of CCS.

Table 4 Summary of ports' environmental strategies

No.	***Port***	***CO2 reduction strategy***	***Perception on the use of CCS***
1	Port of Los Angeles	- Reducing air emissions for public health - Renewable Energy Programme - Zero Emissions Roadmap	Not mentioned in PoLA, but LADWP mentions the use of CCS technology for their coal-fired power plants
2	Port of Singapore	- Emission reduction in terminal operations, shipping, and harbour craft operations - Incentives for green technology system	Not mentioned
3	Port of New Orleans	- Green marine environmental programme	Not mentioned
4	Port of Antwerp	- Low-Emission Zone (LEZ) - Incentive for environment-friendly vessels	Mentioned on 2011, but have not been developed
5	Port of Rotterdam	- Energy transition strategy (wind energy, solar energy, and biomass fuel) - Heat alliance - CCS - Green vessels	Mentioned since 2009, but cancelled on July 2017 due to public opposition to coal-fired power plant

Source: own elaboration based on various sources.

3.5. Chapter Conclusions

CCS projects in general teaches us that the CCS is a significant technology to mitigate global climate change. However, to realise the commencement of CCS, parties involved deal with a lot of challenges from inside and outside of the CCS parties. One of the challenges is to build trust between parties affected by the CCS infrastructure and involved in the decision making, including the stakeholders, government, and the public society. After gaining trust, knowledge gaps should be addressed with the hope to create unbiased decision making by all parties. There should be alignment of communication between the government and the stakeholders. In addition, due to the high risk of the technology, there are financial challenges.

Due to the risks and challenges of implementing CCS, not all industrial clusters have advanced development of the CCS infrastructure. Some take long period of time to develop, some might even be cancelled, and some are not taking a part of it. Not all ports around the world have CCS in their environment strategies. Moreover, not all ports have high source of CO2 emitters such as the PoR. Each port has different types of environment strategies to reduce CO2 emissions, depending on the condition and the needs of the port itself.

Chapter 4. The case of the Port of Rotterdam

The Port of Rotterdam is the biggest industrial-clustered port in Europe, which is located in the south of the Netherlands. We have chosen to study the case of the PoR for two main reasons. The first reason is the competitive position to build the whole CCS infrastructure. These competitive advantages are discussed later in section 4.2 of this study. The second reason is the accessibility of the data sources and people. Information presented in this section is mainly based on desk research and interviews with the experts, including stakeholders and people from institutions related to the CCS project in the PoR.

This chapter consists of 6 sections. In the first, we briefly describe the carbon capture initiative in the Port of Rotterdam. In the next three sections (sections two, three and four), we describe the competitive advantages, benefits, potential risks, bottlenecks, and success factors in the case of the Port of Rotterdam. For each of these topics, we analyse perceptions of different types of stakeholders. In the fifth section, we analyse the potential impact of carbon capture on the competitiveness of the Port of Rotterdam's industry.

4.1. Overview of CC initiative

The CCS Initiative of the Port of Rotterdam is the Rotterdam Capture and Storage Demonstration Project, more commonly known as the ROAD (*Rotterdam Opslag en Afvang Demonstratieproject*). The first project proposal for ROAD was submitted in July 2009 as a joint venture between Uniper Benelux and Engie. These two constituted the limited partnership of the Maasvlakte CCS Project. Uniper Benelux is the supplier of electricity, heat and gas to all customers in Belgium and the Netherlands. In 2016, Uniper Benelux built a coal-fired power plant in the Port of Rotterdam. Engie is a European oil and gas company that produces hydrocarbons and supplies the natural gas in the Netherlands.

According to the ROAD Maasvlakte CCS Project, the vision and the mission of the Port of Rotterdam's CCS Project is as follows:

> *"Vision: In transition to a sustainable energy supply we will have to rely on various transition technologies in order to secure a reliable, efficient and clean energy supply.*
>
> *Mission: Demonstrating that a large-scale, integrated CCS-chain (offshore) can be applied in a reliable and efficient way within 10 years (2020) and can make a substantial contribution to the climate change objectives, and share knowledge and experiences with other industries and countries"*

As previously mentioned, CCS is the chain activity that consists of capture, transport, and storage of CO2. The CO2 is captured from a certain source (such as power plant or refineries) and then it is transported through a specialised pipeline to the CO2 storage field.

In case of the Port of Rotterdam, the main source of the CO2 is from the coal fired power plant owned by Uniper Benelux, applying the post combustion technology retrofitted to the existing infrastructure. The ROAD project is planned to capture 1.1

million tonnes of CO2 per annum. The captured CO2 is compressed and transported through a five kilometre long pipeline onshore and then connected to a twenty kilometre long pipeline across the seabed to the P18 offshore field in the North Sea. The company responsible for the CO2 pipeline is OCAP, which is owned by Linde Gas Benelux B.V. The CO2 will be injected three kilometres below the seabed into the depleted gas fields with an estimated storage capacity of 35 million tonnes.

Figure 3 Geographic position of PoR's CCS
Source: own elaboration based on Buysse & Fonteijn (2012)

However, on the 29th of July 2017, the ROAD project was announced to be cancelled due to financial difficulties, mainly related to the low price of the EU Emission Trading System (ETS). Given this fact, there seem to be no incentive to realise CCS until the price of the EU ETS increases and become more stable. This does not seem to happen in the near future, and, therefore, the decision board of the ROAD project decided to cancel the project and let the Port of Rotterdam continue to develop the part of transport and storage of the CCS chain.

4.2. Competitive Advantage of Port of Rotterdam

The activity in the PoR is highly related to coal, natural gas, heat, and solar energy. The location and condition of the PoR's area has various advantages in creating the CCS infrastructure.

(1) Clustered source of CO2
Until 2016, the PoR's large and dense industrial area consisted of oil refineries, chemical and biofuels manufacturing, edible oil refineries, gas fired power plants, coal and biomass fired power plants, and industrial gases and water plants, presented in detail in Table 5 below (Port of Rotterdam Authority, 2016).

Table 5 Details of industrial cluster in the Port of Rotterdam

Refineries	Number of sites	Sites area (x 1,000 m2)
Oil refineries	6	8,970
Chemical manufacturing and products	42	9,289
Biofuels manufacturing and products	4	553
Edible oil refineries	5	411
Gas fired power plants	9	250
Coal and biomass fired power plants	5	1,325
Industrial gases and water plants	7	483

Source: Own compilation based on the Port of Rotterdam Authority report (2016)

With the industrial area being an abundant source of CO2, this puts the PoR in advantageous position compared to other locations. The CO2 capture and transport system become slightly easier to manage. According to one of our interviewees, Mr. Schoenmakers,

> *"By having the industries and the empty gas fields so close together, it would make the infrastructure cheaper if you have to transport the CO2 over the distance. It's only 5-20 km for transport, instead of 100 km like in other CCS locations. Compared to anywhere else in Europe, the PoR has the source of CO2 so close and clustered."*

Another statement by De Vries (2017) supports the idea,

> *"… there's a lot of clustering of large CO2 emitters, so it is easier to combine them and to make the investments in the infrastructure cheaper."*

So in the end, the geographical advantage of the industrial cluster of the PoR to easily manage and combine refineries within small distances facilitates the financial side of the project.

(2) Spatial proximity to offshore storage
The location of the PoR is relatively close to the P18 platform, the CO2 storage into depleted gas fields. The PoR requires a five kilometre long onshore transport pipeline and a twenty kilometres long offshore transport subsea pipeline to connect the port area with the gas fields. The old platform infrastructure for P18 gas field is very suitable to be reused for the CO2 storage purposes (de Coninck, 2017).

(3) Good knowledge basis and experienced labour
The Netherlands have a good knowledge and research body of the CCS, which consists of various institutions, universities, and technology providers (Mikunda, 2017). The ability and presence of engineers and researchers is mature, compared to other locations (de Coninck, 2017). Furthermore, the role of stakeholders in the port is also an advantage to improve public perception. According to Mr. Holleman,

"Once the general public has something in their mind, they will stick to it. The ones that are trusted are NGOs and the universities. So they can play an important role in explaining about the CCS, what is necessary and what is required."

(4) Existing CO2 pipeline
The PoR has an existing CO2 pipeline, which is owned and operated by Linde Gas Benelux to supply CO2 to greenhouses. Currently, the existing CO2 pipeline covers only some parts of the industrial area in the PoR. This is an advantageous position for the PoR as they would not need to start the CO2 transport infrastructure from zero, because they already have something in place (de Coninck, 2017).

Table 6 below shows different perspectives on the Por's competitive advantage gained from the interviews.

Table 6 Experts' Perspective on the Competitive Advantage

Competitive Advantage	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Clustered source of CO2	✓	✓	✓	✓	✓	✓	✓
Spatial proximity to offshore storage	✓	✓	✓	✓	✓	✓	✓
Good knowledge basis			✓				✓
Experienced labour			✓				✓
Existing CO2 pipeline	✓					✓	✓
Relatively cheaper than other locations		✓					✓

Institutions of interviewees:
1: Port of Rotterdam
2: ROAD2020
3: TNO
4: Royal HaskoningDHV
5: ROAD2020 (Uniper)
6: Gasunie
7: Radboud University

Source: Own elaboration based on the interviews

Some of the aspects from the interviews confirms the competitive advantage of the general CCS projects from around the world, as discussed in section 3.1. Some of the known aspects are the clustered source of CO2, spatial proximity to offshore storage, and the use of existing pipeline for CO2 transport. Some additional aspects gained from the interviews are the good knowledge basis and the experienced labour. Another advantage of the PoR is the relatively cheaper costs for CO2 transport because of the existing pipelines across the port industrial area.

4.3. Risk and Challenges

From the start of the project, ROAD has faced several risks and challenges. Sometimes, there might be new obstacles on the way, even when finding a solution to the previous obstacle (Weterings, 2017). According to several experts that were interviewed in course of our study, there are five main challenges in building the CCS in the PoR. They include technical issues, financial incentives, rules and regulations by the government, permitting, and acceptance by the society.

4.3.1. Technical issues

In the earlier phase of the project, experts found various technological issues in almost every part of the CCS chain. However, most of the earlier technical issues have been addressed, since more institutes started publishing studies on CCS and new projects were launched that could be learned from, such as the Sleipner project in Norway (Holleman, 2017; de Vries, 2017).

The technical issue that still remains is the CO2 storage fields monitoring system. Once the CO2 is stored to the storage fields, the operator of the storage part needs to prove that the CO2 stays in the gas fields and that there is no leakage. Experts believe that since depleted gas fields are used as the CO2 storage, there will be no leakage since the pressure in the storage stays the same. Besides, once the CO2 dissolves in water, the current technology cannot detect its exact whereabouts, and there can be no categorical proof that the CO2 stays in the gas fields (Read, 2017). However, government requires operators of the storage to prove that there is no leakage of CO2 because otherwise, the CCS infrastructure is not beneficial for the environment.

Risks related to technical aspects may appear in the future, however it is most probably to be handled and managed later with the current technology development. The technical issues are seen as in industrial business risks (Holleman, 2017).

4.3.2. Funding

The first challenge in the funding is that the cost of building the CCS infrastructure is very high. The investment can only be done with the involvement of government funding (Read, 2017).

The second funding challenge is the incentives of participating in the CCS chain. The problem arises due to the fluctuation of the European Union Emission Trading Scheme (EU ETS) price. The EU ETS is the world's largest cap-and-trade scheme, the basis of EU's policy is to mitigate climate change and to reduce GHG emissions in a most cost effective way (European Comission, 2017). The ETS price is fluctuating around € 5.00 throughout 2017, which is too low to provide operational incentives and to encourage companies to participate in the CCS chain.

Figure 4 Carbon EU ETS price chart

Source: Market Insider (2017)

There is a gap between cost and revenue, which needs to be balanced in order to provide an incentive (Weterings, 2017). Otherwise, there would be no incentive for the companies to move towards the CCS chain. According to Schoenmakers (2017), in the early phase of the project, which was around 2009, the EU ETS was relatively high, around €15.00, and it was increasing until mid-2011, which was rather promising for the CCS industry. From the carbon EU ETS price fluctuation chart in Figure 4, we can observe that the incentive calculations for the project in the PoR in 2009 used the ETS price between € 30.00 and € 35.00, which differs substantially with the current price. Because there is abundant existence of CO2 in the emissions in Europe, the price of the EU ETS falls. Based on the current price, there seem to be no incentive for the companies to capture their CO2 emissions. Figure 2 shows that the future of CO2 price is not expected to increase giving an incentive for the CCS implementation.

4.3.3. Rules and regulations

The first challenge of rules and regulations is highly related to the funding issue. In order to make CCS beneficial, there needs to be a change in the applicable climate policy in the region (Weterings, 2017).

The second challenge is related to storage. The CO2 storage is regulated by the EU CCS directive, which mentions the polluters pay principle (PPP). The implementation of PPP in various countries is in line with the environmental tax, based on the amount of emissions of the source (Glazyrina, et al., 2005). According to one of the experts that were interviewed for this study, Mr. Read, the Technical Director of ROAD2020,

> *"The person who is responsible for the CO2 storage carries the long-term liability for monitoring the CO2, ensuring that the CO2 stays underground and that there is no leakage. This principle becomes much more complicated when it comes into practice. The principle of "polluter pays" does not apply in the same way when firms emit CO2. Firms do not face a long-term risk when they emit CO2, they just pay for the current carbon price (ETS)."*

The issue with the regulation is that the rules and regulations needs to be adjusted to include the CCS into the climate policy. Otherwise, there will be gaps of rules and regulations in the implementation of the CCS chain. Furthermore, the company liable for each part of the CCS chain needs to be taken care of. There also needs to be a company that manages the whole chain of CCS, which needs to be secured as early as possible (de Vries, 2017).

The third challenge is that the monitoring system needs to be clearly defined within the applicable rules and regulations, including the system of the CO2 leakage measurement, which depends on the government in charge. This is a potential risk in the future because the monitoring standard and leakage measurement is determined by the government. In this case, according to Mr. Read, "*It becomes a problem when future governments require a very expensive monitoring method*."

Considering the possibility of the changing requirements of the monitoring method, it should also be clearly specified in the climate policy and discussed with the stakeholders involved. To see the problem in a policy perspective, there needs to be a sustainable policy from the government that supports the technology. For a longer-term, the rules and regulations need to be the same (Holleman, 2017). Submitting the

proposal of the regulation at an early phase might be a solution to tackle the problem (Rachmadi, 2017).

4.3.4. Permitting

CCS is a new technology in the Netherlands and it requires a number of permits for each parts of the chain. Receiving all the required permits is one of the main challenges of building the CCS infrastructure. The permitting process is very complex and time consuming, it relates to the conflicting provisions of the CCS Directive and needs the involvement of many permitting authorities (Jonker, 2013).

According to Jonker (2013), to build and operate the whole CCS chain in the Netherlands one needs various permits for each part of the chain. To build and operate a capture plant, there needs to be all-in-one permit for physical aspects; water permit; nature protection permit; and emission permit. For CO2 transportation, for example, which is connected with the capturing and the storage, consists of amendment state zoning plan, water and railway act permit, flora and fauna act exemption, and emission permit are required. For the CO2 storage in the P18 storage field, all-in-one permit for physical aspects, storage permit, and emission permit are necessary to be obtained before the operation.

4.3.5. Societal acceptance

Learning from the previous project of the CCS Barendrecht, it has been noted that societal acceptance towards onshore storage field has been negative as people are worried that it might be a very risky and dangerous project. The current CCS project in the Port of Rotterdam has decided to use depleted gas fields, located five kilometres offshore the North Sea basin to avoid public resistance over the onshore storage field.

However, the challenge of gaining public acceptance in the ROAD project is different from the Barendrecht project. As the source of CO2 captured would be from a coal fired power plant, the challenge comes from the public opposition to it. Society views having the CCS as an excuse to (or compensation for) sustain(ing) the coal fired power plant, instead of meeting global climate change targets. A number of experts (de Vries, 2017; de Coninck, 2017; Herzog, 2016) agree with this line of reasoning and think of it as one more lesson learnt from this project.

The Maasvlakte CCS Project has formed the Communications and Public Engagement team that is responsible for communicating objectives, strategy, key messages, activities and materials to the stakeholder. However, reaching out to the society is highly important to gain trust. According to Brunsting, et al. (2011), trust should be gained before handling the information gaps, especially to the local public. One way of doing this is to provide information to the people from these neighbourhoods who will then communicate it to the other people residing in the area. Since these persons are trusted by society, it is easier to address knowledge gaps though these people.

Table 7 below illustrates the perception of different stakeholders of the challenges that can be faced when building the CCS.

Table 7 Experts' Perspective on Challenges of CCS Project

Challenges	1	2	3	4	5	6	7	8	9	10
Technical	✓		✓		✓					
Funding/financial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Society			✓			✓	✓	✓		
Government			✓					✓		✓
Regulation	✓		✓						✓	
Liability		✓					✓		✓	

Note:
1: Port of Rotterdam
2: Linde Gas Benelux – OCAP
3: ROAD2020
4: TNO
5: Royal HaskoningDHV
6: ROAD2020 (Uniper)
7: Gasunie
8: Radboud University
9: Pertamina EP, Indonesia
10: Pertamina EP, Indonesia

Source: Own elaboration based on interviews

We find from the interviews, that all of the experts perceive funding and financial aspects as the main challenge of a CCS project. The next significant challenge is the societal support, regulation, and liability issues. This confirms the findings from the previous CCS projects in other locations which is discussed in section 3.1. CCS projects all over the world perceive costs, financial, and public acceptance as the main challenge of implementing CCS projects in industrial clusters. A few other CCS projects view regulation and liability as a significant challenge. In addition, the future potential risk is the monitoring standards and leakage measurement requirement that is determined by future governments. It is uncertain that the future governments will require the same or less expensive requirements for this technology. There also needs to be a continuity in the policy that stays the same in a longer-term.

4.4. Success factors

The knowledge of CCS around the world is progressing rapidly through numerous studies. There are various factors that can determine the success of the CCS project. Most recent research on the CCS project in the Port of Rotterdam, found four main factors of success for this project:

(1) Public acceptance
The acceptance of public is highly important to the development of the project as its opinion must be taken into consideration in the decision making. Any kinds of protests by society must be minimised.

(2) Economic feasibility
CCS is a very costly investment. Therefore, strategic alliances and relation to the government is needed to allow for more options of funding. It is highly essential to bridge the gap in the funding and thereby, it is important to secure the funding system from the early stage to avoid confusion (Holleman, 2017).

(3) Government support
In addition to the involvement in funding, the consistency of government's support is also important as it shapes the trust of the society towards the actors in CCS projects.

(4) Transparency among stakeholders
There needs to be transparency between all stakeholders. This includes the financial risk sharing by the government with all the companies.

To conclude this section, there are four main factors that are considered to be the key to a successful CCS, which are public acceptance, economic feasibility, government support, and transparency among stakeholders. This confirms the two success factors that are discussed in section 2.5.1, which are the improved access to funding and the consistency of government support (Global CCS Institute, 2013).

4.5. Benefits

There are several perspectives to see the benefit of CCS in the PoR. The benefit differs for each company with different roles within the CCS chain. Some types of industries are able to participate as operators or owners of the parts in the CCS chain. According to the experts (Holleman, 2017; Schoenmakers), there are three parts within the CCS chain that can give different benefits for each of the role:

(1) Capture
The capture part is interesting for companies that create CO2 emissions, which include companies from such industries as coal-fired power plants and chemical refineries. The reason is because the world is more likely to be heading to a decarbonised industry. For industries that release high volume of CO2 emissions, CCS would be very helpful in sustaining the industry. These types of industries would benefit from participating in the capture part of the CCS chain.
(2) Transport
The transport part is interesting for the companies that focus on gas transportation. Moreover, there has been a drop of natural gas demand lately so such companies as Gasunie would see CCS as an opportunity to expand their business.
(3) Storage
The storage part includes maintenance of the connection of onshore pipeline from CO2 sources to the offshore field storage. Companies involved in the storage part are also liable to monitoring the offshore field storage, ensuring that there is no CO2 leakage.

Industries that are not within the core role of the CCS chain, or in other words, only see CCS as infrastructure to store their CO2 emissions, may also benefit from CCS because then they are able to sustain or even expand their business once the policy to restrict CO2 emissions is more stringent (de Vries, 2017). For example, Linde Gas Benelux that operates the CO2 facilitation sees CCS as an opportunity to increase the supply of CO2 to greenhouses. According to Mr. Hage from Linde Gas Benelux,

> *"We have a commitment to the greenhouses that we will always provide supply for the greenhouses with enough CO2. The current situation is that we have two sources for these greenhouses, but if one of the sources is out of production, then we are lacking the CO2, and so we need other sources which we do not have at the moment. Hence, if we can use the CO2 storage fields as a buffer function, then we always have CO2 available to supply for the greenhouses."*

By sustaining or expanding industries' businesses, indirectly, the existence of CCS can save industries, and thus, create investments and provide job opportunities. Until 2016, total employees working in the refineries and chemical manufacturing in the industrial cluster were around 12,000 people (Port of Rotterdam Authority, 2016). It would be beneficial for the people living in the proximity to the PoR.

Having CCS in the PoR area would also improve the image of the companies within the industrial cluster and the image of the port itself (Mikunda, 2017). However, this applies only if the climate policy, specifically on the EU ETS price, is sufficient for providing incentive for companies to operate with the CCS.

4.6. Impact on Port of Rotterdam's industry's competitiveness

Port competitiveness is one of the measures of a port's performance. In the case of the PoR, the impact of having a CCS infrastructure as one of their CSR would affect the attractiveness of the industrial area, thus, affecting the competitiveness of the PoR. However, since the infrastructure implements a new technology aimed to improve the environment conditions, it becomes complex to measure the exact impact on competitiveness. Therefore, we analyse the potential impact of CCS infrastructure to the competitiveness of the PoR by triangulating different perceptions of the benefits of CCS in PoR from literatures and interview with experts.

As mentioned in the previous section, to see the benefit of CCS in the PoR, we need to look from several perspectives: first, from the perspective of the main actors within the CCS chain; second, from the perspective of using CCS as a 'public' infrastructure similar to a waste system, and third, from the perspective of the investors.

In the current situation, when the carbon price in the EU ETS is low, there is no beneficial incentive for the companies to move forward with the CCS operation. However, in the future, when climate policy in the EU is adjusted, the CCS will potentially be beneficial as discussed in the previous section.

The impact of having the CCS in the short-term weakens the attractiveness of the PoR, because companies and investors would see no actual benefits in investing or participating in the PoR's industry (de Coninck, 2017). However, in the long-term when the climate policy is more stringent to CO2 emissions restrictions, it will improve the competitiveness of the PoR, because by then, the PoR will be ready to face the strict climate policy, and companies will be able to enjoy the benefits as it was mentioned in the previous section.

4.7. Chapter Conclusions

The port's connection to a large and dense industrial area, which consists of oil and gas refineries, chemical industries, gas and power plant stations, and waste incineration allows easier CO2 transport management. Being the source of energy production, the industrial area creates an abundant CO2 emission source necessary for CCS. Compared to other industrial clusters, the Port of Rotterdam is relatively close to the offshore depleted gas fields in the North Sea basin – a twenty kilometre long onshore CO2 pipeline that connects to a five kilometre long offshore CO2 pipeline is needed for the infrastructure to reach the offshore gas fields. There are also several used oil platforms that can be used for the CCS chain. Being utilised as natural gas reservoir before, the storage spaces are suitable for the CO2 storage. Due to these geographical, spatial proximity advantages, as well as due to the fact that there are already previous infrastructures available in the Port of Rotterdam, constructing CCS in this area bears much lower costs compared to other locations.

Moreover, the Netherlands have a good foundation for knowledge and people experienced in this field. Researchers have been talking about CCS from the early 2000s and had the first proposal of the ROAD project in 2009. It is certain to say that the knowledge and development progress of CCS in the Netherlands is mature enough.

Even though the PoR has a lot of competitive advantages, the port still faces challenges since the commencement of the project. The challenges include technical issues, funding, rules and regulation, permitting, societal acceptance, and liability issues. The PoR along with the other stakeholders have taken action to face these challenges, and covered the technical and permitting issues. From interviews and research on previous CCS projects on other locations, it is understood that costs and financial issues are the main challenges of implementation of CCS infrastructure, followed by societal support, regulation, and permitting.

The impact of CCS on the PoR can be seen from several perspectives. From the perspective of each role of the CCS chain, the CCS may be beneficial for companies that can be part of the core CCS chain, i.e. capture, transport, and storage parts. For industries that perceive CCS as a public waste infrastructure, they are able to sustain or expand their businesses, which leads to investments and job opportunities, especially for the local residents. For the PoR, they can improve their image as they include CCS in their CSR strategies. The PoR can be leading in global climate mitigation actions and set a good example for the industrial-clustered ports in the world.

Chapter 5. Conclusion

5.1. General Findings

Global climate change has affected the perspective of industries and businesses in the world. Industries, including ports, in many countries in the world are taking action to play a role in climate change mitigation. Governments have sponsored the development of port infrastructures. Ports have adapted environmental strategies that focuses on the CO2 emission reduction to their CSR strategies.

To perform successful port development, the authority needs to put attention on several aspects, which are their 'leadership status', deep understanding on the relevant status, team with good effort and the willingness to take risks, long term view, and support from stakeholders, including the government. It is important also to maintain a sustainable port development by viewing the port from three perspective: economic, environmental, and societal.

Carbon capture and storage (CCS) is a rather newly developed technology to reduce CO2 emission resulting from the production in power plants and other industries that emit high volume of CO2. Many countries around the world are putting their efforts to develop CCS. However, given the fact that not many CCS projects are successful and rather costly investment, the perception of CCS has not always been positive. People with less knowledge tend to find CCS as a dangerous innovation and are mostly opposed to the technology. The fact that the infrastructure is expensive affects political and government support.

There are several factors that would determine the success of a CCS project. A well sustained competitive advantage is one of the most strategic management to perform a sustainable port development. The drivers of a competitiveness of a port include the financial aspect, labour availability, knowledge infrastructure, port policies, and the image of the port.

Stakeholders in a port cluster certainly plays a role in port development, including the transport firms, port labour, port-related manufacturing industries, end users of ports, local environmental groups, local residents, and governments. The stakeholders can be categorised to government organisations, port authorities, and port companies.

5.2. Answering the Research Questions

In this section, we answer each research questions based on the research to make it more structured.

(1) <u>What actions and plans have similar ports made to mitigate global climate change?</u>

We selected five seaports with similar characteristics as the PoR, which consists of industrial cluster area. The selected ports are the Port of Los Angeles, the Port of Singapore, the Port of Antwerp, the Port of New Orleans, and the Port of Rotterdam. Based on the information on the five seaports, all of the seaports maintains to include and adapt their CSR strategies with environmental strategies to reduce CO2 emissions to help mitigate global climate change. Each ports have green port

management systems with different kinds of initiatives, each differs based on the need, the ability, and the competitive advantage of the port.

(2) What are the main lessons from existing Carbon Capture Initiatives?

After studying five existing Carbon Capture Initiatives, we found that there are several lessons that can be learnt from them. The first is that the importance of tax system to the reduction of greenhouse gases. The second is that the CO2 allowance in the climate policy can be used as an incentive to use CCS. The third lesson is long period of time to develop CCS, so the parties involved must be prepared for the long-term commitment to participate in the project. The last is that communication between parties, especially stakeholders and the government, is very important to be maintained and aligned to avoid misunderstanding.

(3) What are the success factors of Carbon Capture Initiatives?

Based on the case study of the PoR, the main success factors of a CCS implementation include society support, economic feasibility, and government support. From previous CCS projects, there are several lessons that can be learnt with respect to the success factors. Climate policy, communication and public outreach are crucial in every project, knowledge dissemination, building of trust securing the financing system at an early stage, and maintaining the relationship between the government and the stakeholders are also very important.

(4) What are the competitive advantages of PoR in realising Carbon Capture Initiatives?

The PoR has several competitive advantages to build and operate a CCS infrastructure in the industrial area. The PoR's competitive advantages are the clustered source of CO2 emissions, spatial proximity to offshore storage, good knowledge and research body, experienced labour in the field, and existing infrastructures that can be used for building a new CCS infrastructure, including the existence of CO2 pipeline.

(5) What are the roles of the (main) stakeholders in a Carbon Capture Initiative?

There are different roles of stakeholders in the CCS project. In the CCS project in the PoR, there are three different roles in the CCS chain, which are the capture, transport, and storage. Stakeholders can play a role on each of the chain requires, depending on the companies' capabilities. The role of capture is taken by the power plant companies. The role of transport is taken by transporting firms and natural gas pipeline providers.

The role of stakeholders in the CCS project success factors is related to the public perception of the CCS and the image of the PoR. It is relatively easy for the stakeholders to spread information to the public as some types of stakeholders, such as NGOs and researchers from the universities, are more trusted by the society.

(6) What are the main risks and challenges of a Carbon Capture Initiative?

There are slight concerns about technical risks in the future, however, it is most probably to be managed as in industrial business risks. The remaining risks that are still worrying is the possibility of changing requirements for monitoring standards and leakage measurements that could change, depending on the future government. Another risks relates to the policy, which also needs to be the same and sustainable to support the CCS technology. Also, based on the perspective of the port stakeholders, the challenges of CCS that still remain include technical issues, funding, rules and regulations, permitting, societal acceptance, and liability issues.

5.3. Limitations

The following are the limitations of the study research:

- There is plenty of information in the form of peer reviewed literatures and articles, news, and experts' opinion on port competitiveness. However, not all of them are applicable to the case of the PoR.
- The response from interview candidates, which were mainly through emails, were quite slow. It is the time of the year that influenced this, because most of the experts from companies were on vacation during the time.
- Triangulation of information from various sources should have been done more carefully for the case of the PoR, but because of the time of the year, some parts of the interviews were conducted quite late. Most of the experts from companies were not at the office for a couple of weeks and therefore, there were only limited time to review all sources and the interviews carefully.
- There was short time between interviews, thus, so little time to analyse the interviews before getting to next one. It would have been more effective if there were significant improvement on each interviews to gain the highly relevant information.

5.4. Further research recommendation

In this section, we describe recommendation for possible further research, which are:

- During this research, the ROAD project was cancelled due to public opposition to coal fired power plant. However, the PoR still aims to continue on implementing the CCS infrastructure. The PoR is planning to continue the development CCS infrastructure on refineries, instead of coal-fired power plant. It would be interesting to discuss the new CCS project with the latest condition of the PoR.
- Viewing the impact of a CCS infrastructure to the added-value of the port.
- The same analysis can be carried out but more focused on the stakeholder management in the port.

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Appendices

Date	:	07/30/2017
Time		10:30
Interviewee	:	Mr. Randolf Weterings
Company/organization	:	Port of Rotterdam
Contact via	:	Direct meeting

What is the current status of ROAD project?

ROAD Project: coal discussion → coal fired power plant (should they shut down or not)

- Capturing CO2 from unit in the coal fired power plant: Maasvlakte power plant (station), owned by Uniper, to an offshore field
- Coal fired power plant need Final Investment Decision (FID) to start up the project
- Port of Rotterdam published a document on 23/03: we want to continue building pipeline and going offshore. Se we now have a pipeline from Shell Pernis to Abengoa (already an existing pipeline), transporting CO2 from both sources to the greenhouses. The greenhouses use 500 000 kT CO2 currently using OCAP pipeline. The OCAP pipeline transport the CO2. What we could do is connect the pipeline to offshore field and all companies in between can start capturing CO2 and participate in storing CO2.
- We are now setting a coalition of willing. Try to set up a consortium with the company so to be really necessary that this is going to happen, for the first phase. And if we can do that then I know for sure that more companies are willing to join. But with this project, what we aim to do is creating a pipeline and storage facility where the companies can get a pipeline in front of their door and they can push the CO2 to it. We don't need the companies to realise it. Although for a business case we need them.
- So, it is not on hold. This is the step that we're in. Pre-feasibility study, I would say.

How about the decarbonised pathways?

- On 23/03, we published Wuppertal study and in there, there are 4 pathways: only one path that doesn't need CCS (Closed Carbon Cycle). Most likely that NL will use CCUS (because only 1 out of 4 that doesn't need CCUS). Combination of 2 or 3 scenarios to make it happen. It's going to be a hub.
- When is it going to happen? 2020-2021 if using the ROAD initiative.

What are the challenges in CCS realisation?

- Technical
- Financial/economical
- Regulatory. We need to change rules, give subsidies because when we started years ago, the expectation is that the ETS price will increase significantly and would still be €6. All those elements need to be changed to really drive the business case and go forward with it. But as a port, we have the obligation to lower our CO2 footprint. In Port of Rotterdam, we have 20% of Dutch CO2 emissions. 90% of 20% is our 15 companies within the Rotterdam industrial cluster. So if we can work those 15 companies it's going to have a huge impact to CO2 reduction. Port of Rotterdam supports and is taking the lead to this initiative. Port of Rotterdam takes the lead and bring the companies together.

About the business case, what are the gap, to the revenues, to the cost, and to see how we can cover that. Also do this with the government, see what the companies itself would like to do in this. It's a long pathway to go to CCS. But we feel that due to Paris Agreement there is a real push in this.

- In Brussels, they would like to see a project coming up on CCUS project. Pilot project. They have a target: SET Program in Brussels. And they have target for CCS, which is seen to be important to realise Paris Agreement. Possible hubs in the world: Port of Rotterdam is with the least cost. In example: Norway. They want to build CCS too. They will cost 5x more than in Rotterdam because companies in Norway are located further away each other. The offshore field is far from the location of the industrial cluster. Advantage of Port of Rotterdam: industrial complex is more centralised. The greenhouses are also nearby, and a part of them is already with an existing OCAP pipeline. So we already have something here, we just have to continue. Already some usage, just need development. Usage of 1 Mton per year for greenhouses. We have a couple of storage fields nearby (20km): P18 (43 Mton) and Q16 (3 Mton). We currently look at the 2 offshore field locations. So to start this project, we only need 20km offshore pipeline. We only need additional pipeline to connect the rest of Rotterdam area. Because half of the port is already covered by OCAP pipeline. More possibilities to speed this up. Brussels which have subsidy program by EU, they really look into Rotterdam to set up the hub because it is 5x less than the second option, which is Norway.

Is OCAP Pipeline involved or not?

- Basically, OCAP pipeline has a maximum capacity. So for the first couple of years will be enough. But if Port of Rotterdam really wants to expand and all companies would join, then the capacity is limited. Most likely: you will have pipeline from Shell to Abengoa, and put a new pipeline next to the existing. So you have OCAP pipeline and a new pipeline. But for the first phase, we (also considering CAPEX) will operate in the existing pipeline. I think 8 Mtons per year can be covered by the existing OCAP pipeline. Seeing from our plans: 10 Mtons. Maximum capacity will be 8 Mton for OCAP, but then they need to invest a lot on building a new pipeline. If investment to new pipeline, we can increase the capacity by 3-4 Mton. If we reach 3-4 Mton, it requires further investigation: do we need new OCAP pipeline with total capacity of 10-15 Mton
- But for the first step, ROAD project as the biggest project so far and will do 1 Mton per year (by coal fired power plant) as the pilot project.
- Hydrogen project

Is there a collaboration between Port of Rotterdam and Port of Antwerp in CCS project?

- Project of Common Interest (PCI): several member states have to be in there. The original plan was to have pipeline from Port of Rotterdam, go offshore, and then go all the way to UK and go south to Antwerp. PCI right now is covering Rotterdam and England part but not yet, still possible, the Antwerp part. In the future, it is logical to have a collaboration with Port of Antwerp, but maybe in phase 3.
- Port of Antwerp has also problem with CO2 and they don't have any offshore storage fields. Storage is much easier in offshore. If having onshore storage fields, you'll have problem with residents.
- Storage in the North Sea is owned by Dutch government, England and Norway.

Who is Port of Rotterdam's competitors?

- Norway
- Brussels.

What is the hardest challenge for Port of Rotterdam?

- Technology
- Economical → ETS price is down, which is out of Port of Rotterdam's control. They can only do lobbying, but not taking decision. There's a gap between cost and revenue, which needs to be leveraged to create an incentive. Otherwise, there would be no incentive for the companies to move forward. Port of Rotterdam's goal is to get the cost as low as possible.
- There are regulations that are difficult. But maybe is already covered by the ROAD project, since they started 5 years ago
- New obstacle on the road. When you work on it, a new obstacle comes up and you try to solve it and ROAD has already done a lot of it. They know exactly and hopefully there would be an important partner in this to give use the lessons learnt of what needs to change, what have been done already.

Who are involved?

- So basically, pipeline is with 'ownership', but serves as a public infrastructure But who participates in utilisation? Anyone within the covered area, just like water and electricity line. Anyone can use that with a transfer fee for pushing their CO2 through the pipeline and having it delivered to either storage fields and greenhouses.
- Shell should participate in CO2 storage because they emit high percentage of CO2.

Who are the stakeholders?

- This is a joint venture project between Uniper (Germany) and ENGIE (France), which are 2 big energy companies.
- Non-disclosure agreement (NDA)

What is the connection between ROAD and Port of Rotterdam?

- The project itself is on the coal fired power plant of Uniper in Maasvlakte. In the project they are also developing the storage field. If we want to develop, the pipeline needs to cover not only Uniper's area, but also other Rotterdam industrial areas, because the companies might want to participate.
- So, Uniper can do the pilot project. Port of Rotterdam can take care of the pipeline (also invest in it), so the pipeline is ours. And we make sure that all companies can participate.
- Decision maker for the whole project: Uniper and ENGIE. But for the pipeline, Port of Rotterdam is the lead.
- Port of Rotterdam signed a contract of the pipeline in the joint venture.

What is the status of the project?

- Setting up coalition of the willing. Have done a lot of research, therefore we will not change projects. We will more likely to be doing a pilot project.
- Detailed organisation is not fixed.

Date	:	12/07/2017
Time	:	13:30
Interviewee	:	Mr. Fred Hage
Company/organization	:	Linde Gas Benelux, B.V.
Contact via	:	Phone call

Until now, what is the capacity of OCAP pipeline that facilitates CO2 transport from PoR?
For transport purposes, the capacity is around 3 million tonnes per annum.

Is your company related to the carbon capture project of PoR?
Yes, we're on the same side as PoR to develop this scheme.

What is your company's role?
In principle, Linde/OCAP will invest in the pipeline towards the Maasvlakte where the CO2 will be transported to before it's injected to a gas field. Besides on being an investor, in the infrastructure in the capture plants, we are the operator in transporting CO2 through the pipeline. We are the owner of the installations: the pipeline, the capture plant, and also the compression (because to transport the CO2 through the pipeline, it needs to be compressed). In other words, providing all the pipelines on shore. For the offshore part, it is not decided yet who is going to be the owner of the gas field. It is still under negotiations between parties, between stakeholders, PoR, and Linde/OCAP.

What do you think is the obstacle or bottleneck of this project?
Main obstacle is when the field is filled, and you close the field. The company on the field is still responsible for the CO2 in the field. Which means they are liable if anything happens in the field, such as CO2 leakage, then they have to pay for it. As an operating company, this is a very high cost event. The liability when the field is full is transferred to the government. This is the main issue at the moment that there is still no agreement with the government on who will be responsible after 5 years the field is filled of CO2. We would need an insurance policy which would cost tens of millions because the high risk and the damage could be very high as well. And so far, there is no insurance company that would provide an insurance for that. The government is the only party that can take over the liability.

How to tackle the obstacles from your point of view?
to have negotiation between all parties.

What would be the benefit for your company?
we would like to use this gas field filled with CO2 as a buffer (means: CO2 is taken out again for re-utilisation). We have a commitment to the greenhouses that we will always provide supply for the greenhouses with enough CO2. The current situation is that for these greenhouses we have 2 sources, but if one of the sources is out of production then we are lacking of CO2, and therefore we need other sources which we don't have at the moment. Hence, if we can use the fields as a buffer function, then we always have CO2 available to supply for the greenhouses. The sources: Linde/OCAP is buying CO2 from Shell refinery and from Oxo Rotterdam in the Europort (bioethanol plant).

What are the success factors of this project?
the success factor is that we achieve CO2 reduction of about 2 million tonnes a year which will not be emitted to the air. And to secure the supply of CO2 to the greenhouses will increase from the fields.

Other than environmental benefits, do you think there would be societal or economic benefits coming out from this project?
We expect is from the greenhouses to switch from co-generation plants to geothermal plans to provide them with the heat. What they need in winter time to heat the greenhouses. And at the same time, when they have the geothermal heat, then they don't need to find natural gas to generate the heat. In other words, the greenhouses are going to have additional source (a sustainable source) of energy. You create an image that you can store CO2 in underground fields, which is not done yet in Europe. I'm sure it is an advantage. But the total impact is still unknown.

Date	:	28/07/2017
Time	:	09:30
Interviewee	:	Andy Read
Company/organization	:	ROAD Project
Contact via	:	Phone call

Do you think that the role of carbon capture is significant in the global climate change mitigation actions?
Yes, it will be significant. If we don't do carbon capture we will fail to hit the carbon reduction target: Paris Agreement, by keeping climate change below 2 degrees Celsius.

How is your perception on the carbon capture initiative?
The joint venture (ROAD2020) is positive about this initiative. The decision of the parent companies (Uniper and ENGIE) is based on carbon capture for coal plants. However, due to public opposition to coal, the coal power plant itself may shut down in a near future. It wouldn't be effective to have CCS in such short amount of time.

Who are competing with PoR in terms of carbon capture implementation?
The CCS project competes with other projects of a kind that needs government funding as well. For this reason, the competition of this project would be the alternative ways in cutting CO2 emissions. The second problem is that it also depends on the fluctuation of carbon price. In terms of receiving funding from the Dutch government, the competition would be the other types of technology that would support the CO2 reduction, such as wind energy, solar energy, and electric cars. They are not cost effective in terms of euros per tons of CO2 in reducing the emission. But it's much easier to explain to the public. So since CCS needs government funding, the primary competition are other demand of the government funds. The competition we face for CCS is not among other CCS projects, its mainly on other alternatives on reducing CO2 emission. The challenge is to persuade the government that the carbon capture is worth doing in order to meet the climate targets.

For the port itself, port of Rotterdam would compete with nearby ports such as Hamburg and Antwerp.

What is the advantage of PoR in realising the project?
Industries and geographical advantages. PoR has a big concentration of emitters (power station, refineries, chemical plants and biofuel plants). The offshore storage fields are quite close to the shore. So it's cheaper to do industrial CO2 hub in Rotterdam than anywhere else in Europe.

What do you think would be the main obstacle/bottleneck of this program? What are the potential risks of having carbon capture? How do you think these should be tackled? Are there any lessons learnt?
Lessons learnt: in the case of Port of Rotterdam, all technical issues are solved. The remaining obstacles are funding, politics, and regulation. Industries cannot pay for CCS because they would increase the prices up. There have been failures in the carbon market, making CCS not economical in practice.

In terms of funding, Port of Rotterdam never take the funding decision earlier and didn't have all the right funding in place. We had an agreement with the Dutch agreement since last year and the Dutch government failed to comply with each side of the agreement, caused by the politics decision over the coal power plants. Not only because the possibility of the coal power plant to shut down, but the parent companies were also unsure that the joint venture would be able to close the deal regarding to public acceptance.

The problem in regulation: related to liability on storage. The first problem is the CO2 storage regulation that is regulated by the EU CCS directive, written on the principle of "polluter pays". The person who is responsible for the CO2 storage carries the long term liability for monitoring the CO2, ensuring that the CO2 stays underground and no leakage. This principle becomes much more complicated when it comes into practice. The principle of "polluter pays" doesn't apply the same when firms emit CO2. Firms don't face a long term risk when they emit CO2, they just pay for the current carbon price (ETS).

Second, there needs to be a clear definition of what kind of monitoring is required and how exactly is leakage calculated. Both of these terms depend on the definitions set by current government. It becomes a problem when future governments require a very expensive monitoring method. This method is also hard to be defined as it is limited to the current technology. It is very difficult to monitor exactly where the CO2 is after it is injected into the storage fields. Once CO2 captured dissolves in water, current technology cannot detect its whereabouts. Therefore, we cannot prove categorically that the CO2 stays in the well. The amount that has to be paid, which is the carbon emission rights, could be very high in 2040-2050. So the company doing storage faces an enormous regulatory risk in terms of the possibility of future governments' monitoring standards and leakage measurements. From Norwegian and UK projects, the conclusion is that long term liability on storage of CO2 must be held by government. If not, the private company will have to have a risk premium, and the government would have to pay for the risk premium and that will make CC expensive. And if the risk doesn't happen, it will mean the private company makes a lot of money.

Do you think more companies are going to be attracted to the port once with carbon capture? Would they be willing to participate?

It depends on how emission is treated in other ports and how the regulation is towards CO2 emission. There's a possibility in 2040-2050 that firms aren't allowed to emit CO2 at all, so firms would want to go to ports with a CO2 hub. Firms that require the use of CO2 in their production will also consider to choose ports with a CO2 hub.

However, given the low price of CO2, we're not in the position to having a penalty for emitting CO2. If Rotterdam forbid firms from emitting CO2, it would require firms to join the hub. Rotterdam will no longer be attractive because firms must pay instead to join the CO2 storage and firms will choose to go to other ports. Rotterdam will be attractive only if there are already a number of genuinely low emission ports around the world.

Other than environmental benefits (or related to climate change), do you think there would be societal or economic benefit coming out from the realization of carbon capture?
Providing hydrogen for transports and industrial processes. And for heating (electric heating, infrastructures)

What is the most appropriate motivation for carbon capture initiative to be realized?
Achieving deep cuts of CO2 quickly. And one of the ways to keep maintaining some of the existing industries and infrastructures. For the port, the danger is if you don't do CCS and you are following the Paris Agreement target then a lot of the industries within the port is going to have to disappear.

Date	:	03/08/2017
Time	:	11:00
Interviewee	:	Tom Mikunda
Company/organization	:	TNO
Contact via	:	Phone call

How significant do you think is the role of carbon capture in the global climate change mitigation actions?

Looking from the size, compared to the large global climate mitigation models that many organisations house, such as Energy Agency, here in the NL is ECN, they run all these models. And all these models suggest that the lowest cost route to decarbonise both power and industrial sectors is the CCS. So it doesn't mean only CCS, but it means the combination of technology, which includes renewable electricity, different types of fuels. But also CCS is really important if you have stringent climate targets you need to quickly reduce your CO2 emissions and CCS is unavoidable, it has to be used. (based on the scientific models)

How is your perception on the carbon capture initiative?

It's an expensive technology, but if you look at the Port of Rotterdam the majority of the emission comes from the coal fired power plants and also the petrochemical industry. For coal fired power plants the only way for them to stop emitting CO2, there's actually 3 options: either to use CCS to capture the carbon, or biomass (to make them less carbon intensive, more carbon neutral), or you turn them off.

Recently the ROAD project has been cancelled, which could have reduced carbon emission by 15-20% and now the only option they got is to close it down if you want them to stop emitting CO2.

So in terms of cost effectiveness, there has been study done to look into what's more cost effective: applying CCS or shutting down the coal fired power plant. Then I would say CCS is cost effective technology.

Who do you think are the competition of Port of Rotterdam in terms of carbon capture project?

In the UK there's some industrial clusters like Port of Rotterdam. They are looking also at capturing CO2. You could say ports on the east coast of the UK. But the thing is, Rotterdam is quite unique. Is one of the biggest container terminal in Europe. There's not a lot of competition with Rotterdam. Antwerp is also large container terminal and they are also looking into CCS. But I don't think competitiveness in this industry is really an issue when it comes to CCS.

What is the competitive advantage of Port of Rotterdam in realising CCS project?

Abundant CO2 storage possibilities and really close by in the offshore field. Good research body of CCS in the Netherlands, institutions, technologies, technology providers. There's a good foundation for knowledge and experience.

Why would organizations/companies want to participate in carbon capture? What's the benefit for them?
It's a way for them to reduce CO2 emissions, which you could look at that by the form that they have to comply with the policy or regulation from the European or Dutch government. And it is also the way for them to improve the image of the company. The environment performance of the company is improved because they emitting less CO2.

What do you think would be the main challenge of realising CCS? What are the potential risk? How do you think these should be tackled?
Main challenge is reducing the energy penalty. Because when you capture CO2 it also costs energy to do it. So finding ways to reduce the energy requirement is important.

How does it work with the ETS price influencing the decision for costs of the CCS?
So CCS will only be able to be a technology that companies would want to invest in if there's an incentive to do that. Then the ETS price is the main incentive to do that in Europe, but unfortunately the prices are so low in the moment. And for the foreseeable future, they probably won't increase to the level that stimulates CCS so meanwhile there needs to be other ways to be supporting CCS while the EU ETS is so low. For instance, government grants like the Dutch government were going to give 180 million for ROAD. So that's the kind of things that are necessary to get CCS up and running in the meanwhile. While climate policy is going to be introduced, generally. Climate policy intensifies the reduction of CO2, but not technology specific. So companies would comply just by being more energy efficient. But for many industries there's a certain point where the energy efficiency doesn't pay off anymore. There aren't more ways to become more efficient. Maybe to go more efficient in the company it would cost more and be not worth it. It may be for some industries it would be more cost efficient to invest in CCS. But first we need a signal from the ETS price. Right now EU ETS price is on EUR 6. To make CCS competitive for some companies, you would need at least EUR 25-30, depending on which kind of installation we're talking about.

What are the factors for the carbon capture to be successful?
Political support is the most important, and also some risk sharing by the government with the companies. So that could be financially risk sharing, basically. Ways to reduce financial burden.

How different is the public acceptance between having CCS with an offshore storage field (ex: Port of Rotterdam) and CCS with an onshore storage field (ex: CCS Barendrecht)?
It's massive. Onshore: nobody wants it. People don't understand the technology. They think it's too easy for people to get hurt. Negative about the technology to scare people, make people think that bad things will happen. So easy for like green peace

escalate risks. Whereas if it's offshore nobody cares. Because it's away from anybody. If it leaks, it only leaks into the sea, and nobody really cares about that.

Do you think more companies are going to be attracted to the port once with carbon capture? Would they be willing to participate?
Yes, I certainly think so if Port of Rotterdam can. And it's most likely be some sort of transport infrastructure that companies can feed their CO2 in and transport storage infrastructure. If Port of Rotterdam can do that then it could be a good incentive for companies to locate in Port of Rotterdam. But only if we get a strong climate policy. Because otherwise, the companies don't need to do anything anyway.

What is the benefit of carbon capture to the port and/or to the surrounding?
Benefit of carbon capture to the Netherlands is to many of these industrial companies that make a huge amount of pollution. And if they don't do anything they could be considered undesirable and would be pushed away. And it would also mean that the jobs will go with them. So by having CCS means that these industries could stay put. Not move away to countries like China, where the pollution level is less stringent. In a way it helps save jobs, for the economy and everybody has a little bit more money, I guess.

So it would be more of societal and economic benefit?
Yes

Would it also help in terms of knowledge?
Yes. If we keep working on the technology, then knowledge builds up. I mean, we've already been working the research of this project on this technology for nearly 10 years in the Netherlands. That's why I said we have a good knowledge basis. And it's also why it's a good country to start CCS in. Because there's so many expertise here already.

In the research, did you learn from previous CCS projects in other locations?
The previous project would probably be Barendrecht project. A lot has been learnt from house communicate with the public. So from that project that failed, what we learnt is what to do, what's to say and what not to say. To align communication between government and industry. That's the part that we learn from there. There's not many CCS project globally, so not really much to learn from.

What is the most appropriate motivation for carbon capture initiative to be realized?
Reducing CO2 emission in a very short time, without major disrupting the power system or the way industries operate.

Date	:	07/08/2017
Time	:	11:00
Interviewee	:	Evert Holleman
Company/organization	:	Royal HaskoningDHV
Contact via	:	Phone call

What is the role of your company in the project?
A: I am working for a company called Royal HaskoningDHV. We are a multinational company. We have about 6.000 people working around the world in approx 30-40 countries (countries with a lot of staffs: the UK, South Africa, Indonesia, India). About the half of the staff (3.000 people) is located in the Netherlands.

The role of RHDHV in the ROAD project is in the (1) permitting; and (2) the Environmental Impact Assessment (EIA), which is the part of the permitting. You have to go through a procedure to describe the difference alternatives for the project and the impact on the environment (any kind of negative externalities).

How significant do you think is the role of carbon capture in the global climate change mitigation actions?
A: It is quite significant. CCS is required to achieve the goals that have been set (Paris Agreement targets). There are different scenarios. If you exclude CCS, you would need to go to very expensive measures, the cost would probably double from having CCS.

How is your perception on the carbon capture initiative? (trade-off between effectiveness on its goal, the cost, and risks)
A: When you look from a professional point of view, CCS is important to achieve the goals. If you see from the different organisations and the general public, they are not very happy with the CCS, especially in the Storage side, there's a distrust. Just about everything that's happening in the sub-surface, and the distrust is that people are afraid that it might leak out and all kinds of disasters might happen. People associate it with dangerous activities. For the offshore, there's hardly any discussion. The public in general still think CCS negatively. Companies are still a little bit reluctant in proclaiming that they are going to invest in CCS because they are afraid that they only get negative publication.

Who do you think are the competition of Port of Rotterdam in terms of carbon capture project?
A: As far as I know, Antwerp is looking into CCS, but I am not aware that they are progressing that much. The ROAD project is actually the only CCS project in Europe which is near realisation. So actually in realising the realisation of the CCS project, the actors are not concerned with any competition. In realising the CCS project, you actually need a lot of time. I think the Port of Rotterdam is ahead in this.

What is the competitive advantage of Port of Rotterdam in realising CCS project?
A: The Netherlands are in a pretty good position, because the CO2 sources are clustered. And because there is the opportunity, especially in offshore of the North Sea, a lot of depleted gas fields that we can use for CCS. As a country, we do have good opportunities to implement CCS. Not very successful yet, but there are good opportunities.

Why would organizations/companies want to participate in carbon capture? What's the benefit for them?
A: The benefit for each kind of companies would be different, because there are actually 3 parts of the CCS: (1) Capture; (2) Transport; and (3) Storage.

(1) Capture part is interesting especially for the industry, such as coal-fired power plant (Uniper). That's what started the ROAD project. But at the end it might be beneficial for the industry, such as the refineries, because it is expected that they will have to reduce CO2 emissions. And if they don't reduce it they'll probably get through the ETS system, through legislation, need to pay more and more, pay carbon taxes. So it's interesting for them to get the opportunity to get to get rid of the CO2 through the CCS.

(2) Transport part might be interesting for companies like Gasunie, transporting natural gas. They see a drop of natural gas demand. They might broaden their scope. There might be other companies as well such as OCAP pipeline, which is already operational. So for those companies it might be interesting to transport.

(3) Storage part is a little bit difficult. Because all the storage, the reservoirs that can be used, are at the moment used by oil and gas companies. And they earn through oil and gas production. They will probably not earn so much by storing CO2. So their business case is difficult. Because when you drill a hole and gas comes out. It's a quick and easy way to earn a lot of money. And we have to put CO2 in the sub surface, then margins will be small. That's a lot of work with just earning a little money. They are getting used to larger benefits from oil and gas activities.

What do you think would be the main challenge of realising CCS? What are the potential risk? How do you think these should be tackled?
A: Challenges: there are technological challenge, which is quite possible. The second challenge is financial, which is more difficult because more parties are involved with different business cases. So if it's beneficial for capture, but not for transport, it doesn't work. Whereas if it's not beneficial storage, but is beneficial for transportation, also not working. So you need to have business case so for all parties involved it is interesting. So the business case, the financial system is important. Public acceptance is important, especially if there's governmental money involved (government funding). There's serious problem with the whole energy transition. People generally say we don't want any windmills in our environmental. For all the different elements they don't want it. But if you don't want anything, nothing

happens and then the transition is not going to work. So there need to be some kind of awareness that we need to take action. So that the public acceptance is aside. So the discussion should not only be on CCS, but CCS as a part of solution of a larger problem. And first of all we need to accept that we have a larger problem. Then people say "yes it's good that we signed the climate agreement" but that has some consequences. People are not really ready to accept the consequences in their day to day life or their direct environment. There needs to be understanding of the consequences and what are the choices are for the realisation. And only then what that's accepted, people may realise that CCS might be very useful solution. But if you only position it as a solution without the larger picture, then there will always be opposition.

Potential risks: I think there would be technical risks, but it would be manageable as in industrial business risks. The risks from a different perspective is policy. To start CCS needs investments, and there needs to be some kind of continuity in policy of the government (Dutch, EU). So that is what is required. For a longer period, there will be rules that stays the same. For example, is the price of CO2 (ETS price) which is quite low at the moment. Nobody is going to invest in CCS when the cost of CO2 is so low. Only when the price of CO2 is high enough and you can expect it to remain high, then it becomes interesting to invest in CCS.

What are the factors for the carbon capture to be successful?
A: Funding and public acceptance is important. Especially when it comes to funding from the public money (government funding).

Do you think more companies are going to be attracted to the port once with carbon capture? Would they be willing to participate?
A: When there's a kind of infrastructure to transport CO2 it will definitely be a plus for the port, for the companies that are aware that there are activities to reduce the emissions that they can capture it and there's no worries in getting rid of the CO2. So If there's an infrastructure, they can just connect to it, it will definitely be a plus for the port.

What is the benefit of carbon capture to the port and/or to the surrounding?
A: For the surrounding: there's a reduction of CO2. The CO2 emission, they react on a global scale, so it doesn't make too much different for the direct neighbourhood. And CO2 concentration are more or less global. So I think for the people in the area, there are a little bit of benefit but not really that significantly.

For Port of Rotterdam it will be an important stepping stone for going to a low carbon economy for them. I think it gives them a positive profile, their image is improved.

Other than environmental benefits (or related to climate change), do you think there would be societal or economic benefit coming out from having carbon capture?
A: I think the Port of Rotterdam will get economic benefits if they attract and keep the industries there (because the port is more or less fossil driven), step by step they will need to change that. Otherwise instead of benefits, they will get problems with their economics. So I think it's important for them to be a healthy port in the future.

And in the research, did you learn from other CCS projects in other locations?
A: yes, we looked into different CCS projects. At the moment there are a number of CCS projects ongoing in the US, in Canada, mainly used for oil recovery. So they put the CO2 and they get additional oil production. That's a number of CCS projects.

A very interesting one is in Sleipner field (Norway). They store CO2 in aquifer (water layer) instead of depleted gas field. Storing CO2 in aquifer which then produce additional pressure. The reason why the Dutch are looking at depleted gas fields are because these kind of fields have lower pressure than the original pressure of the surroundings. And if you fill it up until the original pressure you are not creating additional pressure on the sub surface. But then if you put it in aquifer then you are creating additional pressure.

There are lessons from the technical point of view and there are lessons from the regulation. The regulations, the rule from the government, most of them are written for different situations. The authorities need time to understand how does it work out for CO2 storage. That takes much more time than expected. The lessons that we learnt is that it takes more time when it involves authorities. They need time to understand the consequences, possibilities, and impossibilities. That's important, the general public. It is quite complex in getting the organisation in the capture, transport and storage side for all of them to be connected in the business case. Those are the main issues that we've encountered. Another thing to understand is for the storage side, the discussion on how do we monitor the CO2 within the reservoir. Making sure that is not leaking to the neighbour reservoirs.

Can the stakeholders play a role in the public perceptions?
A: yes, they are important. The general public, once they have a mindset, they will stick to it. The ones that are trusted are NGOs and the universities. So the universities can also play a role in explaining about the CCS, what is necessary and what is required.

What is the most appropriate motivation for carbon capture initiative to be realized?
A: In the end, the motivations are continuing the industry, making agreement, low carbon industry, and avoidable CO2 emissions. Because you always want to reduce CO2, reduce the use of energy and everything. But in the end there will be an amount

of emission that is unavoidable. If you can use that to take that out the carbon cycle and put it back in the subsurface where the molecules are coming from, compared to other solutions, that will be relatively low cost. If you really want to reach the climate agreement targets.

Date	:	08/08/2017
Time	:	14:00
Interviewee	:	Mr. Hans Schoenmakers
Company/organization	:	Maasvlakte CCS Project, ROAD2020 from Uniper
Contact via	:	Direct meeting

What is the role of your company in the project?

ROAD2020 is a joint venture of Uniper and Engie. Both company have the same role. Everything we do in the project is 50/50, about the capture, transport and storage of CO2. The 50/50 basis is in terms of staff, funding, and liabilities.

How significant do you think is the role of carbon capture in the global climate change mitigation actions?

Until the Paris Agreement, it's not necessary. However, after the Paris Agreement, it seems like the only way necessary to meet the target is with CCS. After having the targets in PA, CCS becomes absolutely necessary. It is more cost effective. Other alternative, which involves the use of biofuels.

How is your perception on the carbon capture initiative? (trade-off between effectiveness on its goal, the cost, and risks)

When we start at 2009, the perception was positive because there was a strategic role behind it. The company had a big portfolio of fossil fuel power plant, but now it decreases, so now the strategic role become less and less. Now, Uniper are not as supportive to CCS as before, and for Engie as well.

Reason for no ROAD project?

First reason is financially. The carbon price is very low, around EUR 5 and we calculated EUR 30-35.

Who do you think are the competition of Port of Rotterdam in terms of carbon capture project?

If you look at the big industrial hubs in Europe, because that's where the competition is, I think it would be a big step forward if this area can solve the CO2 issue. All the industrialised area will have to face the problem of CO2. And if you have the conditions that makes it easier and more beneficial to have CCS, I think it puts you in a better competitive position as a port area. For the companies that are already there or plan to invest in PoR they know that they will have to reduce their CO2 emission. If there is an infrastructure available that allows CCS would be a big step forward.

What is the competitive advantage of Port of Rotterdam in realising CCS project?

The physical condition in the area is so condensed. All the industries are so close together. And the empty gas fields are close by. If you compare it to other places in Europe. I think it is a very advantageous position for the port.

In the end, it would affect the finance. By having the industries and the empty gas fields so close together, it would make the infrastructure cheaper if you have to transport the CO2 over the distance. It's only 5-20 km for transport, instead of 100 km like other locations. Compared to anywhere else in Europe, PoR has the source of CO2 so close and clustered.

Why would organizations/companies want to participate in carbon capture? What's the benefit for them?

The main issue for companies to be involved is that these companies are big polluters. They emit a lot of CO2. They know they'll have to reduce because they will be penalised if they don't (carbon tax, or other measures that may be more expensive than the allocation for CCS). That is the reason for companies to participate.

There are other companies involved in the usage of CO2, such as OCAP that is transporting the CO2 to the greenhouses. That company is owned by Linde, a German company dealing with all kinds of industrial gases. There's also the Gasunie, a gas company in the Netherlands. We want to terminate the usage of gas in the Netherlands, so Gasunie is looking for a new role. Transportation of CO2 can be a role, like transportation for residual heat. There are some parties looking for new and to expand their businesses.

What do you think would be the main challenge of realising CCS? What are the potential risk? How do you think these should be tackled?

Main challenge is the CO2 price. Currently it's very low, and it needs to increase and even be stable in a longer period of time to be beneficial to do CCS. There should be less ETS price increase.

For this project it might be too late. What we maybe can do is take the transport and storage, and transfer that role to another party, which in this case might be the Port of Rotterdam and Gasunie. And let them develop further and continue the project.

And later on, the Dutch government, like other European governments will have to think about a supporting system for capture, like now they are supporting the offshore wind. They have funding for the production of power. But the reason that's done is for the reduction of CO2 if you have a subsidy system the balance is the power produced and the price of power produced with and without CCS. But this will take time, so it will be more of something for the future.

The CCS will still continue. Everyone still thinks it is necessary to continue. But the point is that it's the general view. The power industry has alternative to go to renewable energy. So for other industries, such as refineries for steel and cement, they don't have any alternative. They really need CCS. The hope and the expectation is that the CCS will be developed for these kinds of industries. They can take the learnings from what we have achieved so far.

Public opposition to the coal power plant. I think if the source of CO2 was initially other kinds of refineries, there would be less resistance from the public. In early 2010 or 2011 in the project in Barendrecht. At that time the resistance was because it was an onshore field storage, not the source of CO2, because it was from refineries not coal.

What are the factors for the carbon capture to be successful?

We have the incentive system in price. The support from local government in terms of permitting and regulation. And the support from the society. Because you have to store and transport CO2. And the people living in the city have the tendency to be against everything. The authorities should be able to overcome that and talk to the community and prove to them that it is save. The only way to do that is by communicating with the society in a very early stage.

Due to the public opposition to coal, there might be less resistance if the source of CO2 to be transported and stored is not from the coal fired power plant. For example, the CCS from Barendrecht project was accepted by the society. However, they had resistance in terms of the storage field because it was onshore. Lessons learnt from this is perhaps to have offshore storage field and the source of CO2 is not from coal fired power plant.

Source of CO2 maybe from refineries, or maybe companies like Air Liquide in the Netherlands. They produce hydrogen, they emit a lot of CO2. They will probably be the first to store their CO2 to the seabed.

Do you think more companies are going to be attracted to the port once with carbon capture? Would they be willing to participate?

Well, of course there are more factors that are important. But if there is the infrastructure available at the doorstep, it makes a difference. If there is no infrastructure in the area, like Antwerp or Germany, I think there a clear benefit for Rotterdam, a competitive advantage for Rotterdam if it's there.

What is the benefit of carbon capture to the port and/or to the surrounding?

It's a lot about image. If PoR wants to be a green port, the first thing to do is to reduce CO2 emission. That's the big thing for them, the image. Because the climate and CO2 emission affects globally, not restricted to an area. So you cannot save the climate just from Rotterdam, but you can be a very good example for the world.

Other than environmental benefits (or related to climate change), do you think there would be societal or economic benefit coming out from having carbon capture?

It leads to more investments and jobs. The people living in this area they are used to work in the industrial environment. So I think they are experienced. And if the port has new investments, it's good for them because we have new job opportunities. And also good for the region's economy.

Did you learn from other CCS projects in other locations? If yes, what are the lessons learnt?

Yes, we learn from the institute working in the area of CCS, such as the global CCS institute. But there weren't that many CCS projects in the world when we first started the project, there were only pilot projects, which we have one as well. But on our way, we learn a lot from the project in Canada, Saskatchewan, and we maintained a

good relation with the project. So we try to learn from the Saskatchewan in the technical side, to avoid repeating the same mistakes.

But from the institute we learn even from the Barendrecht project, which failed. We learned about the communication with the society. That the need for public support are highly important, not only for the CCS project, but also for other industrial projects.

There is also a very vivid knowledge dissemination around the world. Projects or started projects in all kinds of states are presenting themselves, what their challenges were and vice versa. We also had conventions, seminars, to learn from others.

What is very important: from the beginning, maintain a good relationship with the authorities, and also with the government, including local governments in order to get their support. You have to organise to internalise them in the project organisation. Also try to organise so companies involved can feel the benefit from the project, they can learn, are involved in the decision making from the earlier stage.

Can the stakeholders play a role in the public perceptions?

Yes, what we always try to do is create ambassadors that is not only ourselves telling the story to society but that we use important people or people that are perceived as important, use them in telling the story.

Because people already perceive the ROAD project as a way to sustain the coal fired power plant. We had a former prime minister who was very active in the CCS and he was our ambassador, and it really helped. Society tend to trust these people more than they trust us.

What is the most appropriate motivation for carbon capture initiative to be realized?

I think it is license to operate. It should be the protection of climate for CCS in general. But if you go to the companies, their main argumentation to do CCS is that it allows them to continue or even increase their primary business, because you take away the negative effects of it. As long as these measures weigh up against the costs or anything that is stopping your business, it is okay.

Date	:	11/08/2017
Time	:	11:30
Interviewee	:	Mr. R.M. de Vries
Company/organization	:	Gasunie
Contact via	:	Phone Call

What is the role of your company in the project?
I work for Gasunie. Gasunie is a state owned company. We operate the gas grids. In our strategy, we are also on to operate onshore CO2 pipeline in the Netherlands.

How significant do you think is the role of carbon capture in the global climate change mitigation actions?
We think CCS is an important transition strategy or development. Because if you want to reach climate goals for certain appliances such as industrial we think CCS is necessary. So we mainly see it as something necessary in the industrial sector, not in the energy sector. We think it is significant. If you look at refineries, or steel production, or cement production, or certain chemical plant such as hydrogen production etc, in the short term, it is hard to make it carbon neutral or biological or sustainable. And since we see that it is important to reach climate goals, we think that CCS is one of the best objects to mitigate those emissions.

How is your perception on the carbon capture initiative? (trade-off between effectiveness on its goal, the cost, and risks)
Gasunie is working with PoR and EBN. We are the participant. We perceive it as it is something important. There are a lot that needs to be taken care of. We believe that CCS can only work if there is enough societal and political support. We say it is important that society and politicians to give inputs to this project. If there is no societal and political support, then probably not invest in this project. It's not something we want to push but it's something we think is necessary.

What is the competitive advantage of Port of Rotterdam in realising CCS project?
I think the most important reason for PoR to invest in a carbon neutral port is to gain their license to operate. If you look at the long term goals for CO2 emission in Europe and the Netherlands, we are heading towards a very low carbon economy. And if you look at the PoR, which is an industrial port and a seaport, with a lot of CO2 emissions, I think it's very crucial for them to be successful in reducing CO2 emissions. And I think something like CCS would be necessary for them to reach those goals. Then for the Netherlands, and the businesses, a lot of companies who would want to invest in CCS are global companies, such as Shell, or Air Products, I think Netherlands could be a frontrunner within those global companies, and they could do pilot projects here and see it's a project they can make to large scale. In the Netherlands, there could be companies that would be willing to invest in the CCS, such as building companies, pipeline companies, consultancy so we can be a frontrunner in this topic.

If you look at large CO2 hubs, PoR has a lot of advantages, it is close to the sea, so we're close to the offshore storage of CO2, and then there's already a small pipeline infrastructure (OCAP) in place, and there's a lot of clustering of large CO2 emitters, so it's easier to combine them and to make the investments in the infrastructure cheaper.

Why would organizations/companies want to participate in carbon capture? What's the benefit for them?
I'm not sure if they would want to participate because there's no incentive yet for them to store their CO2. If you look at the ETS system, which is currently the CO2 policy in Europe and the Netherlands, it is just cheap to buy CO2 emission rights. That's what you're competing with.

On the other hand, a lot of companies are working with their internal CO2 price that are higher than the ETS, because they know that countries, especially within the European Union are really serious of reaching the climate goals. They probably expect their company to be forced or incentivised or taxed to get their emissions down in the coming decades. And for most of those companies, CCS is the technology where they can sustain their business, therefore they don't have to make any drastic changes to their business. If you look at refineries, they could still go on with making fuels if they pay for CCS. So I think it's an incentive for companies to invest in CCS today, also because it is something they can roll out globally. On the other hand, it is still way more expensive than the ETS. Then that might be more expensive than their internal CO2 price. Then it's still be hard for companies to invest in companies like that. There's also an important role for the government to incentivise investments like CCS. Either by subsidising it or by taxing it, anything to make the companies invest in CCS.

What do you think would be the main challenge of realising CCS? What are the potential risk? How do you think these should be tackled?
There are three main challenges: the first is the societal and political support; the second is the way companies are incentivised to invest in CCS. How do you start paying for it? Is it mandatory or is there a subsidy? And the third is who do you go to when you want to do CCS. Let's say, CCS has a lot of CO2 which they want to store offshore, but they don't know who to go to yet. What is the company? And that is what we're trying to tackle together with the Port of Rotterdam and EBN. And I think that should be 'one stop shop' infrastructure service, where you just pay a fee and they take away your CO2 just like a waste company. The company make sure they store the CO2 and they transport CO2 and so on. So, we need one company that manages the whole CCS chain, not just one part (capture, transport, or storage).

What are the factors for the carbon capture to be successful?
If the three main challenges mentioned earlier are tackled, I think the CCS should be successful.

Do you think more companies are going to be attracted to the port once with carbon capture? Would they be willing to participate?
In a few decades, yes. Probably when the EU ETS price is enough to incentive companies to invest in the infrastructure. Only then the project will be feasible economically.

What is the benefit of carbon capture to the port and/or to the surrounding?
Benefits: first, the port would be ready for the future. They would already have the infrastructure in place when the climate policy has become more stringent, or more financially feasible to implement. Second, there would be license for emitting companies to be there and sustain their businesses. And third, to make the air quality better.

Did you learn from other CCS projects in other locations? If yes, what are the lessons learnt?
Yes, we try to learn as much what happened in the Netherlands before, projects that didn't go well, such as the ROAD project, the Barendrecht CCS project, projects in the North of the Netherlands. We are also looking at successful projects in Norway: Sleipner project.

Societal part is the most important lessons learnt. So if you look at the Netherlands in 2010 and 2011, where projects were almost ready to go, but didn't go on because there was no societal support. For example, the Barendrecht project, where Shell was almost ready to invest, but there was huge societal protest. In the end, the government listened to the people and decided to shut the project down. So I think that is one of the most important success factor for CCS at the moment.

It is important to listen to the public, and to start a dialogue, discuss with the society. I think we are already making some good choices. We are not working on coal, we are working on industrial project. We are not storing the CO2 onshore, but we're storing it offshore. But still, there is no political decision yet on the large scale CCS. And also there is no societal discussion yet.

Can the stakeholders play a role in the public perceptions?
Yes, definitely. Government, and also NGOs, a large coalition of companies. I think every stakeholder can play a role as ambassadors, or be part of the dialogue. But I think it's really important to have a broad stakeholders field for projects like this. Also similar with large scale wind projects, where there's a lot of societal protest. But because companies, government, and NGOs work together, it's easier to make the project works. And I think for CCS it should work in the same manner.

What is the most appropriate motivation for carbon capture initiative to be realized?
I would say to combat climate change. It's the only way you're working with the CCS.

Date	:	11/08/2017
Time	:	13:00
Interviewee	:	Dr. Heleen de Coninck
Company/organization	:	Radboud University
Contact via	:	Direct meeting

What is the role of your company in the project?
Our role in the carbon capture is very limited. We have one project related to carbon capture and storage which is starting probably next month. That's a project called the Acorn, which is a CCS project in Scotland. It's making use the old oil and gas infrastructure in the North Sea for CO2 storage. To transport the CO2 in the pipeline, making use of the old offshore platforms and also the old pipelines. One of our roles in the project is looking whether that would be feasible for Rotterdam as well, because there's also offshore platforms that are going to be retired soon, and that could be used for the CCS infrastructure.

How significant do you think is the role of carbon capture in the global climate change mitigation actions?
Yes, I think it is significant. How big it needs to be is still unclear. It might cover 10% of global mitigation. So of the total global emission reduction probably a minimum. It depends on whether we will see negative emissions. Many people who work on climate change they think it is a very good option because it means you can lower the concentrations of CO2 in the atmosphere. And I think biomass and CCS is a really good combination for PoR. And also the role of industry, refineries.

How is your perception on the carbon capture initiative? (trade-off between effectiveness on its goal, the cost, and risks)
I'm not necessarily positive about it. But I'm afraid we need it, we don't have a choice. If you look how different industries are resisting doing something about climate change, reducing emissions and really making the changes that are needed. If PoR wants to keep the refineries and industries in business, and you want to reduce CO2 emissions, you basically need CCS.

Who do you think are the competition of Port of Rotterdam in terms of carbon capture project?
At the moment, people see CCS as very costly. So it would be bad for the competitiveness of PoR, because it's expensive. However, in the long run, it might be positive to the competitiveness of PoR for whether industries are settling there and expanding their activities. At the moment, not. For the future perhaps yes

What is the competitive advantage of Port of Rotterdam in realising CCS project?
Large concentration of sources of CO2 that relatively easy to capture. Relatively close to suitable storage capacity. And there's old infrastructure that can be reused (that's what we're seeing in Acorn). Pipeline, well. Reusable infrastructure. Knowledge infrastructure. Ability and presence of engineers is mature compared to other places.

Why would organizations/companies want to participate in carbon capture? What's the benefit for them?
At the moment, not, because it's so expensive. In the end, they have to because they just don't have a choice. But if government and others eventually decide that

something seriously needs to be done about climate change, then a lot of companies will not have a choice. Companies are not really eager to use CCS, but they have to. Some companies that emit CO2 will probably, in the short-term, supply heat to households. And in the longer-term, do the CCS.
Some companies might gain benefit from it, like selling the technology, the operators, even oil and gas companies.

What do you think would be the main challenge of realising CCS? What are the potential risk? How do you think these should be tackled?
Cost, but it actually depends on how to price the CO2. In the end, is there a real political will to do something about climate change. There needs to be a consensus between the public and governments around the world, not just in the Netherlands or in the EU. The sense of urgency, strong enough, that needs to lead to the very costly measures that are needed. At the moment the balance is still not enough. Things are changing, but not enough.

What are the factors for the carbon capture to be successful?
Public acceptance, economic feasibility, political support, technical feasibility.

Do you think more companies are going to be attracted to the port once with carbon capture? Would they be willing to participate?
That depends on the circumstances. If all around the world, politicians are saying we need to reform how we do industries, how to produce. Every port around the world would have restrictions of CO2 emissions. Then ports with CCS infrastructure will surely be attractive. However, if not, it doesn't really matter for the certain conditions. But IF, climate change policy really happens, then yes.

Other than environmental benefits (or related to climate change), do you think there would be societal or economic benefit coming out from having carbon capture?
Not so much but perhaps the concept "just transitions". The concept of "just transition" is the transition that serve justice. They look much more at the disadvantaged people or groups that are becoming even more disadvantaged. It is basically to soften radical changes, for example to sustain jobs in industries by having CCS and sustaining business.

Did you learn from other CCS projects in other locations? If yes, what are the lessons learnt?
Barendrecht project: wrong in the public acceptance. That's why ROAD project went offshore. It's cheaper to capture from certain refineries than from power plants. Because then the CO2 captured is pure, and the process is easier.

(1) Coal fired power plant (Kemper) that went over budget.
(2) One in California DF2, BP.
(3) Stakeholders play a role in public perception

What is the most appropriate motivation for carbon capture initiative to be realized?
To mitigate climate change.

Date	:	27/07/2017
Time	:	05:40
Interviewee	:	Mr. Agung Prasetyo
Company/organization	:	Pertamina EP, Indonesia
Contact via	:	Email

Do you think that the role of carbon capture is significant in the global climate change mitigation actions?
Very significant, because the volume of CO2 that can be captured and stored into the storage field can be very large.

How is your perception on the carbon capture initiative?
It is the application of method and new technology in Indonesia, by re-storing CO2 as built-in product with the gas production from a storage well, then being injected again into the underground reservoir or used to help releasing natural oil with enhanced oil recovery method.

What is the reason for organizations/companies to participate in carbon capture?
It is in line with the company's business strategy to commit on green energy and CCS utilisation is one of the method to help increase oil production through EOR.

Who are your competitors in the implementation of the carbon capture initiative?
There is no domestic competitor, only financial support from a number of instances, mainly foreign companies. Some companies abroad have done the pilot project earlier even though it is still a few.

What do you think would be the main obstacle/bottleneck of this program? What are the potential risks of having carbon capture? How do you think these should be tackled?
The main obstacles are regulation, use of funding for research and development, and company or organisation authorised to use CCS.
The potential risk is being rejected because practically CCS' role is not the part of the main business and is a costly investment.
Our act to anticipate the risks and obstacles is by being included to the national program to reduce emission and by involving institutions and universities.

What are the success factors of the carbon capture initiative?
Involvement of government's function because the project includes several institutions and department, either environmental, energy, universities, transportation, forestry, local government, monetary, and approach to local residents.

Do you think more companies are going to be attracted to the port once the carbon capture is implemented? Would they be willing to participate?
If the industrial cluster is close to the port area, it would probably be attractive and one of the ways can be done by planting more trees as much as needed, measured by the emission of the manufacturing firms and the ability to absorb emission through green plants.

From your point of view, what is the benefit of carbon capture to the port and/or to the surrounding?
It would be beneficial to the environment and help balance the environmental despite the port activities that produce a lot of emissions.

Other than environmental benefits (or related to climate change), do you think there would be societal or economic benefit coming out from the realization of carbon capture?
Following this kind of project, there would be education on the importance of living environment, education about CCS, community development to gain public acceptance on CCS.

What is the most appropriate motivation for carbon capture initiative to be realized?
The motivation is to maintain the balance of the Earth's system, to sustain lives in the earth from the damage of globalisation and to avoid any natural disaster that can happen in the coming future.

Date	:	31/07/2017
Time	:	07:30
Interviewee	:	Mr. Herman Rachmadi
Company/organization	:	Pertamina EP, Indonesia
Contact via	:	Email

Do you think that the role of carbon capture is significant in the global climate change mitigation actions?
Yes, very significant.

How is your perception on the carbon capture initiative?
It is very good to reduce global climate change (global warming)

What is the reason for organizations/companies to participate in carbon capture?
To increase the corporate income because the existence of CO2 in hydrocarbon reduces the selling price.

What do you think would be the main obstacle/bottleneck of this program? What are the potential risks of having carbon capture? How do you think these should be tackled?
The main challenge is to gain government's approval, who acts as the regulator, because the cost of building the plant is very high.
The potential risk is the long period of execution, which is more than 2 years.
Our act to anticipate the risks and challenge is by submitting the proposal, including the engineering design, to the regulator earlier and to quicken the construction time.

What are the success factors of the carbon capture initiative?
The success of the CCS project depends on the effectiveness and the efficiency of the CCS technology.

Do you think more companies are going to be attracted to the port once the carbon capture is implemented? Would they be willing to participate?
Oil and gas companies might be uninterested because it has no influence on their economic aspect.

From your point of view, what is the benefit of carbon capture to the port and/or to the surrounding?
The biggest benefit would be to the environment, to reduce global warming.

Other than environmental benefits (or related to climate change), do you think there would be societal or economic benefit coming out from the realization of carbon capture?
Yes, from the societal aspect, CCS might provide more employment. For the economic aspect, CO2 is needed for some industries, such as shipyards and soft drinks.

What is the most appropriate motivation for carbon capture initiative to be realized?
The motivation is to improve the economy.