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Value chain analysis of CO_2 storage by using the ECCOTool: A case study of the Dutch offshore

Daniël Loeve[a*], Filip Neele[a], Chris Hendriks[b], Joris Koornneef[b]

[a]*TNO, The Netherlands*
[b]*Ecofys, The Netherlands*

Abstract

A detailed analysis is presented of the short and medium term development of CCS in The Netherlands. Scenarios for CCS development were constructed by combining the most recent estimates of offshore storage capacity, for both depleted gas fields and saline formations, with expected timing and volumes of captured CO_2 from two industrialised regions, the Rotterdam harbour area and the Eemshaven area in the north of the country. Individual emitters in both regions were approached to obtain realistic growth profiles for captured volumes. This paper explores the cost of transport and offshore storage of CO_2 and explores the benefits of the two regions in joining their storage efforts. Further work is ongoing and will focus on the CCS value chain, to provide the emitters with insight in the cost structure of transport and storage. Furthermore, the study will provide the basis for a national CCS implementation plan.

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Keywords: CCS, CO_2 storage; value chain analysis; storage economics; ECCOTool

1. Introduction

In 2010 and 2011, TNO has performed the Independent Storage Assessment (ISA) studies, Phase 1 Phase 2 and Phase 3 for the Rotterdam Climate Initiative (RCI) [1 – 3]. These have resulted in an overview of options for storing CO_2 in the North Sea. The next step in supporting the development of CCS is to analyse choices in transport and storage, cost drivers and options for cooperation to relevant parties in the Rotterdam harbour and Eemshaven (in the north of the country).

The primary objective of work presented here is to support the RCI in developing, in close cooperation with CO_2 emitters in the industrialised areas near Rotterdam and Eemshaven, an analysis of the cost of transport and offshore storage of CO_2. The aim is to explore different options, such as joint use of transport and storage infrastructure, and the availability and cost of offshore storage sites. Such results are to support the emitters in Rotterdam and Eemshaven in preparing for CCS in forming a common view of the economics and risks of a set of CO_2 transport and offshore storage initiatives. In this way, this study will support large-scale demonstration projects in Rotterdam and Groningen by demonstrating any benefits of third-party contributions, as well as possible commercial/contractual arrangements and financing structures for each option. Once completed, the results of the study will provide a basis for engaging with potential participants in a CCS network and with the Dutch government and other key stakeholders on formulating a national plan to address these complex issues.

Thus, the study presented here aims to support the RCI in bringing the development of CCS in The Netherlands to a next level. By doing that, the project will help RCI reach its goals:

- To form a common understanding of the costs and risks of pursuing alternative CO_2 offtake pathways,
- To identify the near term actions to ensure their feasibility, and
- To facilitate the necessary strategic and commercial discussions among emitters, between the two regions and with external parties, including transport and storage operators and government.

One of the outputs of the above process will be a ‘CCS implementation plan’ (IP), that will be developed within the Dutch CCS programme CATO [4] to support government and other stakeholders.

This paper presents the first results of analysing a number of scenarios of the development of CCS from the two regions involved. The scenarios demonstrate the value in cooperation between the regions.

2. Method

The analysis of the CCS development scenarios was performed with the ECCO Tool. This tool was developed for techno-economical analysis of complex CCS chains. The main objective of ECCO Tool is to facilitate strategic decision making regarding early and future implementation of CO2 value chains for Europe. The tool itself is presented in a separate papers [5 - 8].

CCS development scenarios were constructed along the following lines. Figure 1-3 shows a sketch of the elements of the CCS transport and storage structure.

- *Storage*. Offshore storage capacity data were produced by recent screening studies and detailed site characterisation work on several offshore depleted gas fields and saline formations [1-3]. The availability of the gas fields, i.e., the expected year of end of production, as currently given by operators, was used as the first possible year of injection. In all scenarios, the Rotterdam storage and capture demonstration (ROAD) project [9] is used as the starting point. The ROAD project plans to use the nearby offshore depleted gas field P18 for storage. Its capacity is about 40 Mt. Once the P18 field is full, the adjacent P15 gas field is assumed to be developed; it has a comparable capacity. Once these two fields are filled, an offshore saline formation is to be developed for CO_2 storage. Its capacity is 200 Mt, of which about half results from depletion through production of the oil fields within the formation. The remaining 100 Mt is assumed to be feasible through overpressurising the formation (an approach also taken by the Sleipner project).

- *Transport: pipelines.* In this study, all transport is by pipeline. Ongoing work considers ship transport, as an alternative, and to compare the cost of both options. The first pipeline will be line constructed by the ROAD project, with a capacity of 5 Mt/yr, to the P18 gas field. While the ROAD demonstration project will produce about 1 Mt/yr, the pipeline will be gradually used to its maximum capacity, once other parties in the Rotterdam harbour will deliver captured CO_2. Once the P18 and P15 gas fields are filled up, a large pipeline of about 110 km length will be constructed to the saline formation in the Q1 offshore block. Its capacity will be larger and assumed to be 10 Mt/yr. This will be sufficient beyond 2040, based on the expected growth profiles of captured volumes used in this study.

A second, large pipeline is to be constructed from Eemshaven in the north, also to the Q1 formation, with a length of about 220 km. It is assumed that the pipelines from Rotterdam and Eemshaven connect to the same storage location.

- *Transport: hub.* Rotterdam has the ambition to develop a CO_2 hub, a collection point for CO_2 streams from the harbour region, as well from neighbouring countries, serving as a gateway to the storage capacity in the North Sea. In the scenarios used in this study, capture installations in the Ruhr area are assumed to contribute to the CO_2 volumes out of Rotterdam through shipping along the Rhine. The cost of the hub installation are represented in the ECCO Tool, which can be used to study its business case (investment, operational costs, tariff structure, etc.).

- *Capture*. Individual emitters in the two regions were contacted about their potential contribution to the development of captured volumes. Timing and expected volume were used to construct a growth profile of CO_2 available for storage.

3. Cost data

In the ECCO Tool, each element of the CCS chain can be treated separately, at the required level of detail. In this study the transport and storage cost were modelled, each techno-economic module in the ECCO Tool needs a number of input parameters in order to calculate the capex and opex figures. These input data is specific for each pipeline and storage location. In order to model the CCS chain cost data were collected from literature and public data, like the ZEP report on storage and transport [10,11], the ISA studies performed for RCI [1-3] and more reports, which can be found in the list of references below [12-16].

CO_2 transport can be transported in a high or low pressure pipeline system, within the Rotterdam harbour area the collection network is modelled as a low pressure network, because of densely populated area. Other pipelines (offshore and Eemshaven collection network) are assumed to be high pressure systems.

The main cost of a pipeline is the construction itself, the capex of the pipeline mainly depends on the distance, terrain (e.g. offshore/onshore) and additional cost like trenching trough the beach. The fixed and variable opex are monitoring and maintenance cost, which is modelled according to the ZEP report

The capex costs of the storage operator consist of an initial investment to change the production platform into an injection platform, furthermore incremental costs for additional compressor/wells/platforms and finally an abandonment cost. The opex is modelled labour and energy cost for injection and monitoring, also each 5 year a well workover is modelled. The actual numers are taken from the EBN report.

The following costs are modelled: mothballing of potential storage sites, closure and abandonment of wells not in use and financial liability transfer. These cost items are very uncertain and therefore not taken into account.

The cost development of macro-economic parameters like (e.g. oil price, electricity price) is captured in a macro economic scenario called “happy planet” [8]. This scenario means a combination of high economic growth, low fuel availability and low degree of environmental change, which suggests that the climate changes were actively addressed by EU and on a coordinated worldwide basis leading to a reduction of greenhouse gas emissions. In order to achieve that, technology reducing the emissions must have been successfully implemented while fossil fuels use continued. That again was leading to depletion of the reserves and thus the increase in fuel prices. High prices of fossil fuels made the renewable and other alternative energy productions competitive.

4. Scenarios

The CCS development scenarios considered in this paper are the following:

- Scenario 1:Rotterdam only. In this scenario, the Eemshaven region does not cooperate with Rotterdam (Figure 1).
- Scenario 2: Eemshaven only. This scenario will serve to demonstrate the cost of transport and storage for the Eemshaven region, when it does not join forces with Rotterdam (Figure 2).
- Scenario 3: Rotterdam and Eemshaven. This is the scenario illustrated in Figure 3. Both regions develop CCS and jointly operate storage in the Q1 saline formation. While the Rotterdam region first develops storage in the P18 and P15 fields and moves to the Q1 formation as a second step, the Eemshaven region, as it is located north-east of Q1, uses it for storage from the start of CCS. In due time, the two regions jointly operate the Q1 site.

These three scenarios were used to obtain estimates of the following:

- Total cost (capex, opex) of developing CO_2 transport and storage from Rotterdam and Eemshaven;
- Benefit for each region when joining efforts in storage;
- Cost of storage in a large saline formation (Q1), as compared to storing in depleted gas fields (P18 and P15).

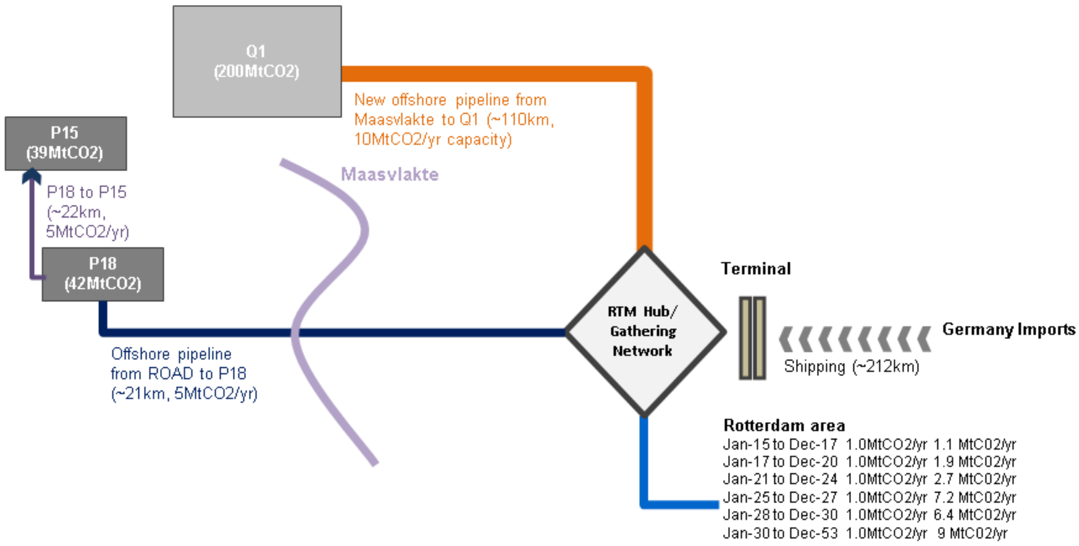

Figure 1: Schematic layout of the scenario 1, which is used to analyse the development of offshore CCS in. Only the Rotterdam harbour is taken into account. In order to fill up all available storage capacity the injection period from Rotterdam area is increased until 2053.

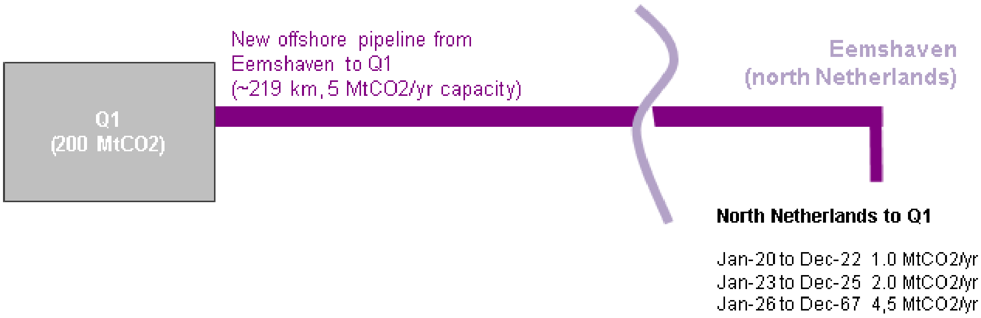

Figure 2: Schematic layout of the scenario 2 which is, used to analyse the development of offshore CCS in. Only the Eemshaven harbour is taken into account. In order to fill up all available storage capacity the injection period from Eemshaven area is increased until 2067.

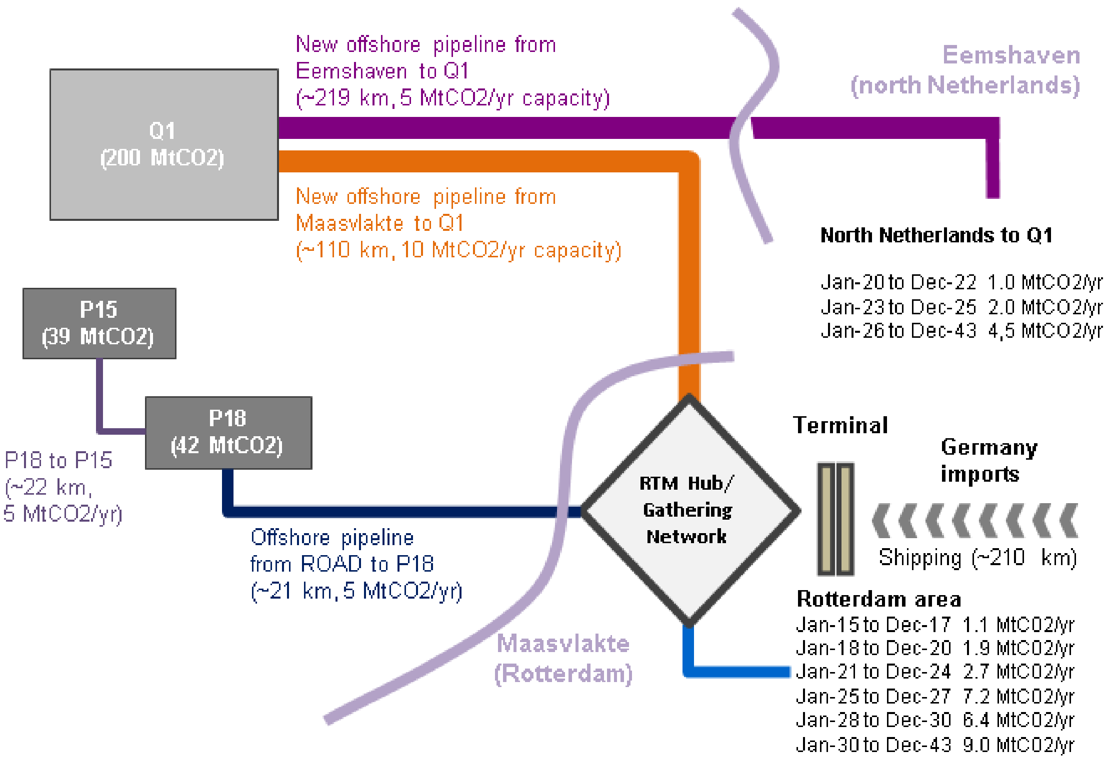

Figure 3: Schematic layout of the scenario 3 to analyse the development of offshore CCS in The Netherlands. Two industrial regions are represented: Rotterdam and Eemshaven. The Rotterdam harbour (lower right), where a hub is modelled, which collects CO_2 from capture installations in the harbour area and CO_2 shipped from Germany. Storage capacity is available in the short term in two nearby depleted gas fields (P18 and P15) and a large saline formation (Q1). Dedicated pipelines transport the CO_2. In the Eemshaven area (upper right), located in the north of the country, a coal-fired power plant is planned, producing 5 $MtCO_2$/yr. Storage is foreseen also in the Q1 saline formation. While the lay-out as shown in the figure represents one scenario, other scenarios considered include the Rotterdam only, or Eemshaven only. A comparison between these scenarios is presented in the text.

5. Results

The results of each scenario described in the previous section is summarized in a table in the next subsections.

5.1 Rotterdam are only

Table 1: Cost of transport and storage in Scenario 1

Rotterdam only		capex (Meuro)	opex (Meuro)	stored (Mton)	(euro/ton CO2)
Transport	Rotterdam harbour network (inc. compression)	64	58	-	-
	Pipeline to p18/p15	115	12	-	1,6
	Pipeline Rotterdam to Q1	179	19	-	1,0
	Total transport cost	**358**	**89**	**-**	**1,7**
Storage	P18/P15	235	306	77	7,0
	Q1	52	606	190	3,5
	Total storage cost	**287**	**912**	**267**	**4,5**
Total cost		645	1001		6,2

The cost for the Rotterdam only scenario in table 1 shows that the cost per euro/ton CO_2 for the depleted gas field is twice as high compared to the Q1 aquifer. The reason for this difference is the injectivity is decreasing over time for the P18/P15 fields and therefore incremental investments have to be done to increase the injection capacity, such as additional wells and compressors.

The cost for transport is also lower for Q1 compared to P18/P15. The relatively high capex for the pipeline from Rotterdam to Q1 is compensated by the larger volume transported so therefore cost in euro/ton decreases.

5.2 Eemshaven only

The cost for the Eemshaven only scenario in table 2 shows that the cost of transport per euro/ton CO_2 is not so different, the pipeline to Q1 is longer and more expansive from Eemshaven, however the Rotterdam harbour has a more complex collection network and therefore the transport cost for both areas are almost equal. The storage cost for Q1 is almost equal for Eemshaven and Rotterdam, however the opex in Rotterdam is a little lower because the total period of injection is shorter due to higher injection rates (9 $MtCO_2$/yr from the Rotterdam area vs. 4.5 $MtCO_2$/yr from the Eemshaven area).

Table 2: Cost of transport and storage in Scenario 2

Eemshaven only		capex (Meuro)	opex (Meuro)	stored (Mton)	(euro/ton CO2)
Transport	Eemshaven harbour network	13	26	-	-
	Eemshaven pipeline to Q1	279	42	-	1,6
	Total transport cost	**292**	**68**	**-**	**1,9**
Storage	Q1	52	657	196	3,6
	Total storage cost	**52**	**657**	**196**	**3,6**
Total cost		344	725		5,5

1.1 Rotterdam and Eemshaven area together

The result of this scenario is that the total cost of the transport and storage is equal to 7.0 euro/ton CO_2, which more expansive compared to the Eemshaven only scenario (5.5 euro/ton CO_2) and for the Rotterdam only scenario (6.2 euro/ton CO_2). The two regions are competing for a limited storage capacity of the Q1 aquifer (200Mt). The consequence is the injection rate is relative large into the aquifer Q1, which can lead to additional investments. However the Q1 aquifer has a great injection capacity, which is also reflected in the cost of the different scenarios. The storage cost estimates do very between 3.2 to 3.6 euro/ton CO_2.

The real reason of the cost difference is the transportation of CO_2 to the aquifer Q1. Two regions are sharing one storage location, as a consequence each region is transporting less CO_2 to this storage location. The final result of this observation is the transport is on an euro/ton basis more expansive.

In order to be more conclusive and complete on the best choice for the emitters this research will be extended for the whole Dutch Continental offshore.

Table 3: Cost of transport and storage in Scenario 3

Rotterdam and Eemshaven		capex (Meuro)	opex (Meuro)	stored (Mton)	(euro/ton CO2)
Transport	Rotterdam harbour network (inc. compression)	64	53	-	-
	Pipeline to p18/p15	115	12	-	1,6
	Pipeline Rotterdam to Q1	179	11	-	1,8
	Eemshaven harbour network	13	12	-	-
	Eemshaven pipeline to Q1	279	19	-	3,2
	Total transport cost	**650**	**107**	**-**	**2,8**
Storage	P18/P15	235	306	77	7,0
	Q1	52	569	196	3,2
	Total storage cost	**287**	**875**	**273**	**4,3**
Total cost		937	982		7,0

2. Conclusions

This paper presents the first results of a financial and economic analysis of the development of CCS from two industrialised area in The Netherlands: the Rotterdam harbour and the Eemshaven area in the north. The results demonstrate the benefits of the two regions cooperating in developing and exploiting the offshore storage capacity. While the first projects are expected to develop from the Rotterdam harbour, capture projects in the Eemshaven area will have the choice of either joining the transport and storage system from Rotterdam, or developing their own offshore storage. These two approaches were compared, showing the benefit in each case for the two regions involved.

The analysis is currently ongoing and will result in a detailed analysis of the CCS value chain, for different elements of the CCS value chain (capture, transport, storage) and focusing on the options for the individual emitters. This will provide the emitters with a common view on the development and cost structure of different transport and storage options. The study will also produce the basis for developing, together with the national government, an implementation plan for CCS.

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