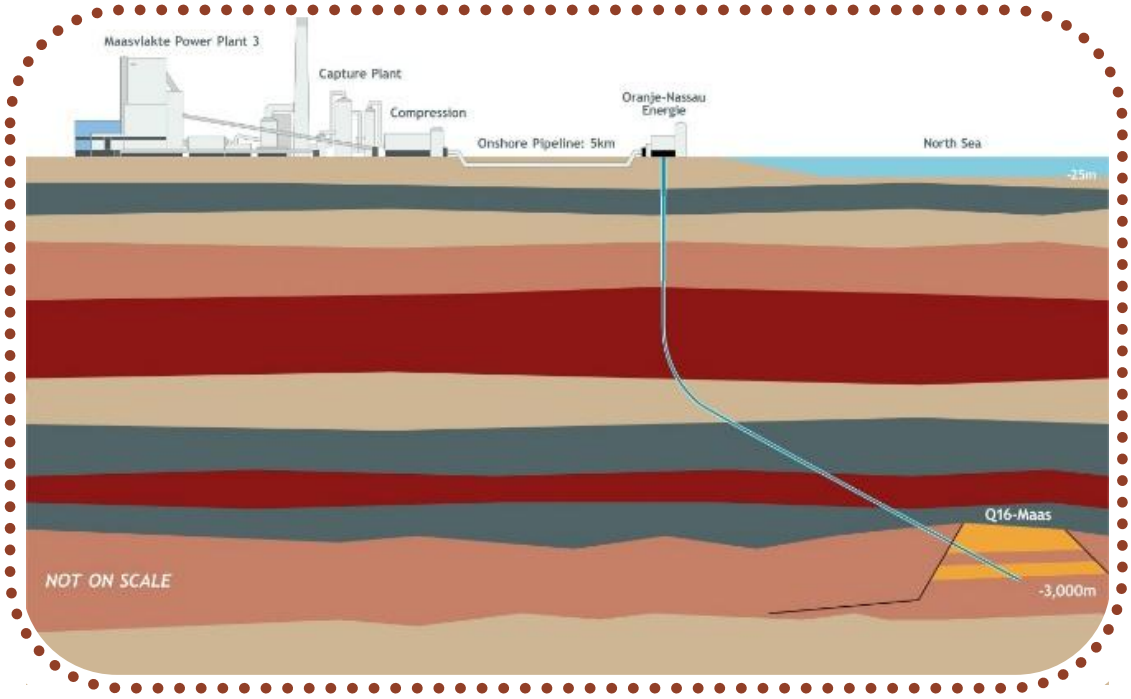
Public Close-Out Report Overview

Rotterdam Opslag en Afvang Demonstratieproject



Maasvlakte CCS Project C.V.

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Public Close-Out Report 1 of 11: Overview

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Index of ROAD Public Close-out Reports

No	Title	Scope
1	***Overview***	***Introduce and summarise the public close-out reports.***
2	Capture and Compression	Technical report covering capture, compression and power plant integration.
3	Transport	Technical report covering CO_2 pipeline transport.
4	CO_2 Storage	Both technical and commercial aspects of CO_2 storage for ROAD. Subsurface work required to demonstrate permanent storage is described.
5	Risk Management	The risk management approach used by ROAD.
6	Permitting and Regulation	Description of the regulatory and permitting framework and process for the ROAD project, including required changes to regulations.
7	Governance and Compliance	Company structure and governance for Maasvlakte CCS Project C.V., the joint venture undertaking the ROAD Project
8	Project Costs and Funding	A presentation of the projected economics of the project, with both projected income and costs.
9	Finance and Control	Description of the financial and control systems, including the costs incurred and grants claimed.
10	Knowledge Sharing	Outline of the Knowledge Sharing & Dissemination plan as developed by the ROAD project and completed KS deliverables and actions
11	Public Engagement	Description of how ROAD organized and managed the Public Engagement process.

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1. Introduction

The ROAD project was one of the leading European CCS Projects from 2010 to 2017. During that time, a great deal of project development and engineering work was completed, including full design and procurement to allow a possible FID at end 2011 or early 2012.

This report gives the overview of all the public "close-out" reports written after the formal decision to terminate the project was made in September 2017. This set of reports is designed to present the knowledge gained and lessons learnt from the ROAD Project in an accessible form. The reports cover technical issues, financial issues, risk management, permitting and regulation. The objective is to give future CCS project developers, knowledge institutes, researchers and other interested parties the maximum opportunity to use the knowledge gained and lessons learnt by the ROAD project team.

The general project description is given in the next section. This is followed by the index of ROAD close-out reports, with a brief summary of the highlights from each report.

2. General Project Description

The ROAD Project is the Rotterdam Opslag and Afvang Demonstratieproject (Rotterdam Capture and Storage Demonstration Project) which ran from 2009 to 2017, and was one of the leading integrated Carbon Capture and Storage (CCS) demonstration projects in the world.

The main objective of ROAD was to demonstrate the technical and economic feasibility of a large-scale, integrated CCS chain deployed on power generation. Previously, CCS had primarily been applied in small-scale test facilities in the power industry. Large-scale demonstration projects were needed to show that CCS could be an efficient and effective CO_2 abatement technology. With the knowledge, experience and innovations gained by projects like ROAD, CCS could be deployed on a larger and broader scale: not only on power plants, but also within the energy intensive industries. CCS is one of the transition technologies expected to make a substantial contribution to achieving European and global climate objectives.

ROAD is a joint project initiated in 2009 by E.ON Benelux and Electrabel Nederland (now Uniper Benelux and Engie Nederland). Together they formed the joint venture Maasvlakte CCS Project C.V. which was the project developer. The ROAD Project is co-financed by the European Commission (EC) within the framework of the European Energy Programme for Recovery (EEPR) and the Government of the Netherlands. The grants amount to € 180 million from the EC and € 150 million from the government of the Netherlands. In addition, the Global CCS Institute is knowledge sharing partner of ROAD and has given a financial support of € 4,3 million to the project. The Port of Rotterdam also agreed to support the project through investment in the CO_2 pipeline.

In the first phase of the project, 2009-2012, the project was developed to final investment decision (FID) based on using the P18-4 gas-field operated by TAQA as the CO_2 storage location. This required a pipeline of approximately 25km from the capture location (Uniper's coal-fired Maasvlakte Power Plant – MPP3), about 5km onshore and 20km off-shore.

Unfortunately, the collapse in the carbon price undermined the original business case, and in 2012 a positive FID was not economically possible. The project then entered a "slow-mode" in which activities focused on reducing the funding gap, either by reducing costs or by securing new funding. In late 2014 a possible new funding structure was identified, and explored in 2015 and 2016. This included additional grants for operation and cost reductions. The cost reduction that could be successfully applied was to change storage sink to a newly developed field, Q16-Maas, operated by Oranje-Nassau Energie (ONE). This smaller field was much closer, with only a 6 km pipeline required. This resulted in a remobilization of the project late in 2016, and development of the new scheme. However, in mid 2017 work was again halted, and the grant formally terminated in November 2017.

The ROAD project design applied post combustion technology to capture the CO_2 from the flue gases of a new 1,069 MWe coal-fired power plant (Maasvlakte Power Plant 3, "MPP3") in the port and industrial area of Rotterdam.

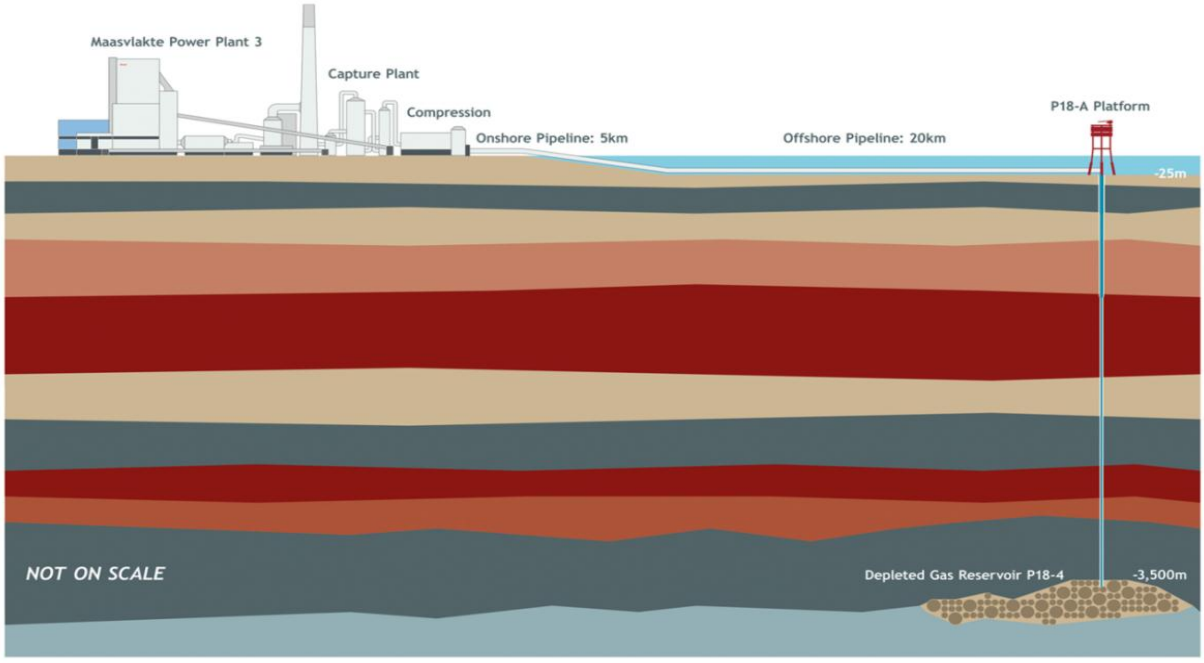
The capture unit has a design capacity of 250 MWe equivalent. During the operational phase of the project, approximately 1.1 megatons of CO_2 per year would be capture and stored, with a full-load flow of 47kg/s (169 t/h) of CO_2. For transport and storage two alternatives were developed as described above: storage in the P18-4 reservoir operated by TAQA; and storage in the Q16-Maas reservoir operated by Oranje-Nassau Energie.

After a competitive FEED process, Fluor was selected as the supplier for the capture technology in early 2011. The plant was fully engineered, and long lead items contracted for, ready for an FID in early 2012. All the necessary permitting was completed, with a permit for the capture plant being granted in 2012. Following the delay to the project, an updated design was developed with Fluor in 2017 incorporating lessons learnt from research and development in the intervening years, changes to the MPP3 site, and the impact of the changes to the transport and storage system. A revision to the permit was under development when the project was halted.

For Storage in P18-4

From the capture unit the CO_2 would be compressed and transported through a pipeline: 5 kilometers over land and about 20 kilometers across the seabed to the P18-A platform in the North Sea. The pipeline has a transport capacity of around 5 million tonnes per year. It is designed for a maximum pressure of 140 bar and a maximum temperature of 80 °C. The CO_2 would be injected from the platform P18-A into depleted gas reservoir P18-4. The estimated storage capacity of reservoir P18-4 is approximately 8 million tonnes. Figure 2.1 shows the schematic illustration of this.

Figure 2.1: Schematic overview of the ROAD Project using storage in P18-4



P18-4 is part of the P18 block which also includes the larger P18-2 and also a small field, P18-6. These depleted gas reservoirs are about 3.5 km below the seabed under the North Sea about 20km from the Dutch coastline, and have a combined CO_2 storage capacity of around 35 Mt.

The ROAD Project with storage in P18-4 was fully developed for FID at the end of 2011, including all engineering, regulatory and permit requirements. A CO_2 storage permit was granted in 2013, the first such permit in Europe. Unfortunately, a positive FID was not possible due to funding problems, and in 2012 technical project development on P18-4 was halted.

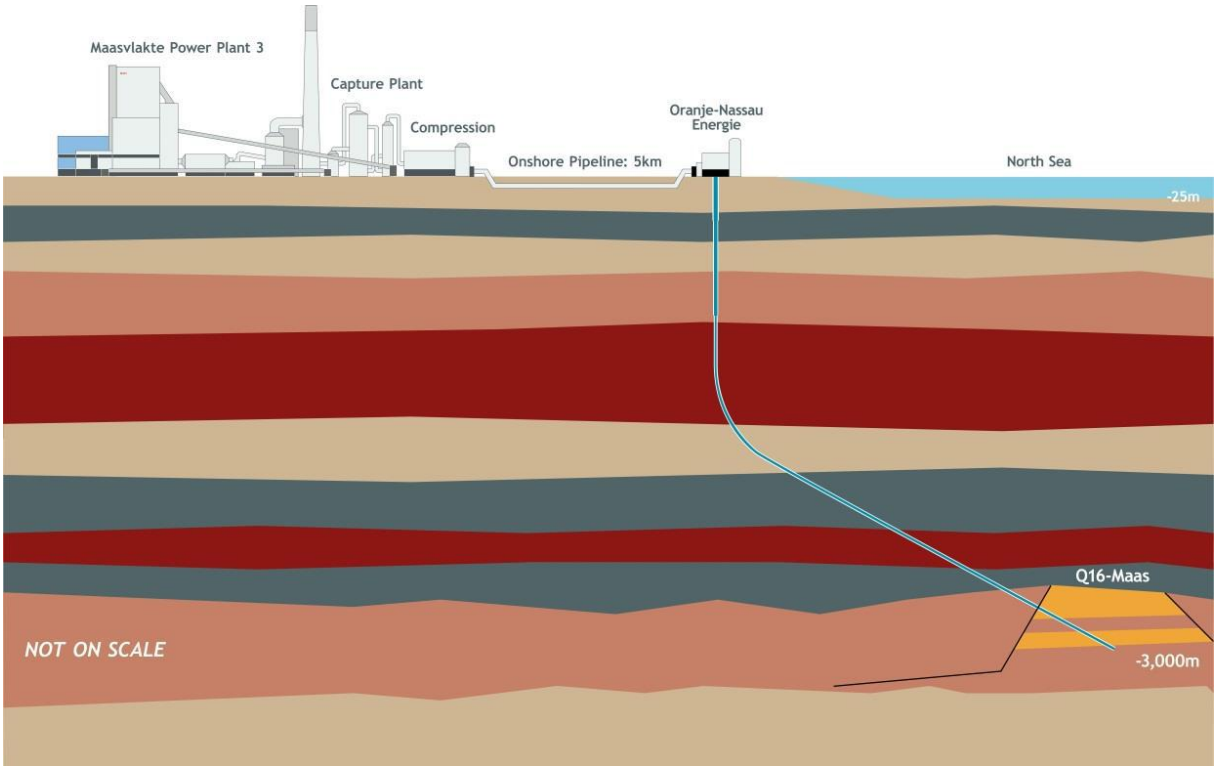
For Storage in Q16-Maas

From the capture unit the CO_2 would be compressed and transported through a pipeline over land to the current ONE-production site Q16-Maas (Figure 2.2). The selected pipeline design would have a transport capacity of in excess of 6Mt/year. It was designed for a maximum pressure of 40 bar although in the first phase operation at 20 bar was planned. Final compression to injection pressure (around 80 bar) would be at the injection site.

The Q16-Maas reservoir is located just off-shore from the Maasvlakte, and is reached by a long-reach well, drilled from on-shore. The well is about 5km long, and travels approximately 3km down to reach the reservoir depth, and 3 km horizontally (off-shore) to reach the reservoir location. The reservoir is relatively new (production started in 2014) and was not due to finish production until 2022. Therefore this scheme involved the drilling of a second well to accelerate gas production and so allow CO_2 injection to start in 2020. This second well would also allow co-production of modest amounts of condensate (and possibly natural gas) during CO_2 injection. The estimated storage capacity of reservoir Q16-Maas is between 2 and 4 million tonnes.

This reservoir was identified as a possible storage location only at the end of 2014, with project development running through 2015-2017. Due to funding uncertainties, the work focused on feasibility, cost estimation and concept design to the level required for permitting. Therefore a lower level of detail is available for this storage location, compared to P18-4. It should also be noted that unexpected water production was experienced from Q16-Maas in 2016, leading Oranje-Nassau Energie to issue a revised reservoir model and production plan in May 2017. Since this was only shortly before the ROAD work was halted, the ROAD plans for Q16-Maas were not fully amended to reflect this new production data.

Figure 2.2: Schematic overview of the ROAD Project using storage in Q16-Maas



3. Overview of ROAD Close-out Reports

The full list of close-out reports with a brief summary of the highlights is given in the table below.

No	Title	Scope	Highlights
1	Overview	Introduce and summarise the public close-out reports.	Success of CCS is determined by the funding and business cases, not by technical issues. All technical and permitting issues proved to be solvable, or at least manageable.
2	Capture and Compression	Technical report covering capture, compression and power plant integration.	The full-scale capture plant was designed and procured to the standard required to enable FID. The report describes the plant including technical challenges overcome, and how some leading technical risks that remain were managed. The technology can therefore be considered to be available for full scale post-combustion capture.
3	Transport	Technical report covering CO_2 pipeline transport.	Safe and practical designs to transport the CO_2 were developed. The optimum transport solution depends on the storage location and characteristics.
4	CO_2 Storage	This report covers both technical and commercial aspects of CO_2 storage for ROAD. The extensive subsurface work required to demonstrate permanent storage is described.	Safe permanent CO_2 storage can be demonstrated for depleted off-shore gas fields. Existing data from gas production was sufficient for characterization and permitting. Commercial arrangements covering construction and operation were also achieved. However, ROAD's proposed solution for storage liabilities requires help from Government, and it not certain if it would have been successful.
5	Risk Management	The risk management approach used by ROAD, with summary of risks as at 2011/2012.	Reference report for project and risk managers. A conventional risk management approach was successfully applied to the ROAD project.
6	Permitting and Regulation	Description of the regulatory and permitting framework and process for the ROAD project, including required changes to regulations.	ROAD was the first CCS project successfully permitted in the Netherlands and in the EU under the CCS Directive, with some changes to existing regulations required. Good communication and close co-operation between the project and regulatory authorities were essential, and significant extra time was required. However, ROAD's proposed solution for storage liabilities was not fully tested.
7	Governance and Compliance	Company structure and governance for Maasvlakte CCS Project C.V., the joint venture undertaking the ROAD Project	Brief technical report explaining the company structure, governance and compliance with company regulations.
8	Project Costs and Funding	A presentation of the finances of the project in both phases,	This is the report for those wanting to understand the economics of CCS and how to build a business

		with both projected income and costs.	case. It explains the expected costs and income for the ROAD demonstration in both set-ups, covering capital costs, operating costs and abandonment.
9	Finance and Control	This describes the financial and control systems, and records the costs incurred and grants claimed by the ROAD project.	This description of the financial controls, reporting issues and reporting methodology is written from a financial control / reportingl viewpoint to inform readers bidding for other large EU grants how the ROAD Project handled reporting. It also records the actual incurred project costs and grant funding claimed in the period 2010-2017.
10	Knowledge Sharing	Outline of the Knowledge Sharing & Dissemination plan as developed by the ROAD project and completed KS deliverables and actions	This report outlines the Knowledge Sharing & Dissemination plan as developed by the ROAD project. It describes the Knowledge Sharing & Dissemination approach, strategy, partners and action plan. It also provides a list the completed Knowledge Sharing & Dissemination deliverables and actions.
10	Public Engagement	Description of how ROAD organized and managed the Public Engagement process.	This report decribes how the ROAD project organized and managed the Public Engagement process. It explains how the Public Engagement function was an integrated part of the project organization. It also describes the development and implementation of the Public Outreach plan.

4. Conclusions

The ROAD project was a genuine trailblazer for CCS in Europe. Successes included:

- FID-ready, permitted capture plant design for coal-fired power plant at 250 MW_e scale
- Successful design of interfaces along the whole power plant, capture, transport and storage chain
- Innovative transport solution with warm CO_2 and pipeline insulation developed.
- Handling of injection of CO_2 into low pressure depleted gas reservoirs successfully engineered.
- First CO_2 storage permit under the CCS Directive granted, with permanent geological storage in TAQA's P18-4 gas field proven to the satisfaction of Dutch and EU regulators.
- Robust understanding of costs and risks for the full-chain CCS project developed.
- Regulatory barriers to permitting successfully overcome (including change in law) through a close co-operation with the regulators.

However, the ROAD Project was ultimately unsuccessful. Remaining high-level challenges, unsolved by the ROAD Project were:

- Lack of sufficient business case (whether funding, incentives and/or market mechansms) for CCS. ROAD was a project without a customer.
- Lack of public and/or political acceptance of coal-fired power generation. This may prove to be a generic challenge for any fossil-fired process where there is a perceived renewable alternative.

- The liabilities under the CCS Directive for CO_2 storage are currently either unacceptable for commercial parties, or add a substantial risk premium. These liabilities are largely out of the control of the project developer, and are best carried by Government.

The knowledge, experience and innovations gained by the ROAD Project are presented in the close-out reports. It is hoped that this experience will make a substantial contribution to future CCS deployment.