REVIEW OF PROJECT PERMITS UNDER THE LONDON PROTOCOL – AN ASSESSMENT OF THE PROPOSED P18-4 CO_2 STORAGE SITE

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Review of project permits under the London Protocol – An assessment of the proposed P18-4 CO_2 storage site

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Executive summary

The London Convention and Protocol is one of the first global agreements to protect the marine environment. The London Convention, established in 1972, will eventually be replaced by the London Protocol which was agreed in 1996, and entered into force in 2006. The Protocol promotes the protection of the marine environment by prohibiting the dumping of wastes and other matter into the sea. Under the Protocol all dumping is prohibited, with the exception of a limited number of selected wastes on the so-called "reverse list", which can be considered. There are currently 46 Parties to the Protocol, of which the Netherlands is one of them.

In 2007, an amendment entered into force which permitted CO_2 streams to be considered for dumping under the London Protocol. The amendment was shortly followed up with a set of “Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations”, developed to support the National Authorities of Contracting Parties in evaluating permit applications for CO_2 disposal activities in their marine territories. As few offshore CO_2 storage sites have been permitted in the territories of Contracting Parties, there is no evidence of the application of the above mentioned guidelines to actual permitting processes.

The P18-4 field is a near-depleted gas field at a depth of 3.5 km under the seabed, located approximately 20 km off the Dutch coast in the North Sea. The operator of the gas field applied for a CO_2 storage permit to the Dutch authorities in 2011, for the storage of a maximum of 8 Mton CO_2. An irrevocable storage permit for P18-4 was provided to the operator in September 2013, however the project has been postponed indefinitely due to economic constraints.

The objective of this report is to assess to what extent the proposed P18-4 storage site, originally part of the ROAD CCS Project, complies with the London Protocol’s 2012 Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations, and therefore the 1996 London Protocol itself. The assessment has been achieved through a simple, but systematic, cross-check of the requirements of the Specific Guidelines against the contents of the application material provided by the operator to the National Authority. This involves the appraisal of approximately 1100 pages of submitted material in order to identify evidence of compliance.

In the case of the P18-4 CO_2 storage permit, the material submitted to the National Authority is broadly sufficient to allow an evaluation of the planned CO_2 storage activities in a manner consistent with the provisions of the 1996 London Protocol. Based on the information submitted by the applicant, this compliance assessment indicates overall technical compliance with the CO_2 Specific Guidelines, no information was sufficiently absent that would indicate clear non-compliance with the CO_2 Specific Guidelines.

There are, however, eight areas from within the application material whereby the information or justification is partially sufficient, but may require further clarification. In addition, there is also one area of partial compliance and one of non-compliance from within the permit conditions which is the responsibility of the National Authority.

A number of recommendations are provided to address the shortcomings that have been identified by this assessment. The recommendations are relevant both for this specific case study, but also for future CO_2 storage permits in marine territories of contracting parties. The recommendations are categorised according to the stakeholder group:

Recommendations to the National Authority

- It should be requested that within any future permit applications, that the applicant makes a statement recognising the applicability of the 1996 London Protocol and the requirements of the Specific Guidelines for Assessment of Carbon Dioxide for Disposal into Sub-seabed Geological Formations.

- Recognizing the focus of the London Protocol on protecting the marine environment, the applicant should provide a clear statement on the foreseen effects of CO_2 leakage on the marine environment, including seawater, sediments and biota. The statement should be based on the outcomes of the risk assessment. Should the outcome of the risk assessment indicate a negligible risk to the marine environment, and this is acceptable to the National Authority, no further site-specific effects assessment of CO_2 on the local marine environment would seem applicable. If pre-existing information is available on the marine communities, tidal effects, sediment conditions, etc. at the site or at a similarly indicative area, these could be considered for inclusion. There are several EU projects which may be useful in this respect, such as RISCS, QICS and ECO2.

- The applicant should explicitly highlight an “Impact Hypothesis”, which could be an additional concise statement as part of the outcome of the standard risk assessment.

- For future permit allocations for CO_2 storage sites provided by the National Authorities of Contracting Parties, it is recommended that a brief summary of conformance with the requirements of the 1996 London Protocol is included in the preamble to the permit conditions. The summary should focus on the Impact Hypothesis and demonstrate that consideration has been given to the marine communities at the storage location.

- If it has been decided not to develop an Action List, due to a limited number of CO_2 streams for storage, this should be explicitly mentioned as part of the LP compliance summary recommended above.

- The National Authority should ensure that fixed intervals for permit review are explicitly mentioned in the permit conditions.

Recommendations to the London Protocol

- Clarification could be sought on the extent to which the applicant must comment on the economic and operational feasibility as a consideration in the selection of a sub-seabed geological formation for the disposal of CO_2 streams.

- Clarification could be sought on the extent and nature of public participation recommended in the permitting process of CO_2 storage sites, given a lack of experience and suitable legal provisions for enforcing such participation in some Contracting Parties.

1 Introduction

This report has been commissioned by the IEA Greenhouse Gas R&D Programme (IEAGHG) to support them in highlighting permitting experiences of proposed CO_2 storage sites in relation to the guidelines and criteria of the London Protocol. To achieve this, the contents of the CO_2 storage permit application for the proposed CO_2 storage formation of P18-4, originally part of the ROAD CCS Project, has been assessed against the Specific Guidelines for CO_2 disposal agreed by the Parties of the Protocol in 2007.

1.1 Background

1.1.1 The London Protocol

The "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972", the "London Convention" for short, is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.[1]

In 1996, the "London Protocol"[2] (LP) was agreed to further modernize the Convention and, eventually, replace it. Under the Protocol all dumping is prohibited, except for possibly acceptable wastes on the so-called "reverse list", listed in Annex I of the Protocol. The Protocol entered into force on 24 March 2006, and there are currently 46 Parties to the Protocol.[3] The Netherlands is a Party to the London Protocol.

1.1.2 CO_2 sequestration in the London Protocol

In 2006, in recognition of the potential damage that human induced climate change could have on the marine environment and the emergence of carbon capture and storage (CCS) as a promising mitigation option, the LP was amended to add CO_2 onto the list of possible acceptable wastes which could be “dumped”. In fact, it was agreed that “Carbon dioxide streams from carbon dioxide capture processes for sequestration” could be considered for dumping (Annex 1, Para 1.8), only if:

1. disposal is into a sub-seabed geological formation; and
2. they consist overwhelmingly of carbon dioxide. They may contain incidental associated substances derived from the source material and the capture and sequestration processes used; and
3. no wastes or other matter are added for the purpose of disposing of those wastes or other matter.

[1] IMO, 2016. Accessed (15.01.2016): http://www.imo.org/en/OurWork/Environment/LCLP/Pages/default.aspx
[2] http://www.imo.org/en/OurWork/Environment/LCLP/Documents/PROTOCOLAmended2006.pdf
[3] IMO, 2016. Accessed (15.01.2016): http://www.imo.org/en/OurWork/Environment/LCLP/Pages/default.aspx

The amendment entered into force on 10 February 2007 for all Contracting Parties to the Protocol.

The consideration of dumping material on the so-called “reverse list”, must adhere to the general requirements of Annex II of the LP, which covers, *inter alia,* a waste prevention audit, consideration of waste management options, characterisation of the waste, dumpsite selection, assessment of potential effects, monitoring, permit and permit conditions.

Given the specificity of CO_2 sequestration, a CO_2 Working Group was established by the London Protocol Scientific Group to consider and produce guidelines for the assessment of CO_2 sequestration in sub-seabed geological formations. In November 2007, the “Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations”[4] were adopted by the Parties to the LP. This 14 page document, provides additional guidance for CO_2 sequestration projects to comply with the requirements of Annex II.

In addition to the Specific Guidelines, the “Risk Assessment and Management Framework for CO_2 Sequestration in Sub-Seabed Geological Structures”[5] (RAMF) was also adopted in October 2006, which aims to provide generic guidance to Parties on the characterisation and management of risks of CO_2 sequestration to the marine environment.

1.1.3 Criticism of the inclusion of CO_2 sequestration in the London Protocol

The non-government environmental organisation Greenpeace is generally unsupportive of CCS as a climate change mitigation technology, raising questions regarding safety and cost, while considering CCS as a distraction from efforts to accelerate the wider proliferation of renewable energy.[6]

Members of Greenpeace have expressed concerns regarding the inclusion of CO_2 as a substance on the LP “reverse list”, allowing it to be considered for marine dumping in the sub-seabed. As an observer body to the LP, the organisation considers the decision to include CO_2 streams to have been made too hastily.

A particular concern of the organisation is the absence of reporting on the application of the Protocol’s Annex II and the CO_2 Specific Guidelines to offshore CO_2 storage sites which are currently being developed within the marine territories of some Parties to the Protocol.[7] The originally proposed P18-4 storage site of the ROAD CCS Project (Rotterdam, The Netherlands), and the proposed Goldeneye storage site of the Peterhead CCS Project (Peterhead, United Kingdom), are examples.

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[4] http://www.imo.org/blast/blastDataHelper.asp?data_id=31124&filename=2012SPECIFICGUIDELINESFORTHEASSESSMENTOFCARBONDIOXIDE.pdf

[5] http://www.imo.org/en/OurWork/Environment/LCLP/EmergingIssues/CCS/Documents/CO2SEQUESTRATIONRAMF2006.doc.

[6] Greenpeace, 2008. False Hope - Why carbon capture and storage won’t save the climate. Accessed (15.01.2016): http://www.greenpeace.org/international/Global/international/planet-2/report/2008/5/false-hope.pdf

[7] Santillo, D & Johnson, P. 2014. Issues in international regulation of CCS…the case of the London Protocol. Accessed (16.01.2016): http://www.slideshare.net/UKCCSRC/david-santillo

Greenpeace states that the absence of evidence of the application of the LP's obligations and guidelines could be detrimental to transparency and trust within the LP. During the LP Annual Meetings, the organisation has often called for evidence of compliance to be made explicit by relevant Parties.

1.1.4 The P18-4 storage location

The P18-4 field is a near-depleted gas field at a depth of 3.5 km under the seabed, located approximately 20 km off the Dutch coast in the North Sea. P18-4 is one of a number of gas fields in the P18 and P15 licensing blocks on the Dutch continental shelf of which TAQA Offshore B.V. holds the production licenses. The gas production has reduced the field pressure from 350 bar to 20 bar, and the field has since been identified as a highly suitable CO_2 storage formation, with an approximate capacity of 8 Mton CO_2. The P18-4 field is produced through the P18-4A2 well, connected to the P18-A platform. The P18-4 field continues to produce a small amount of natural gas.

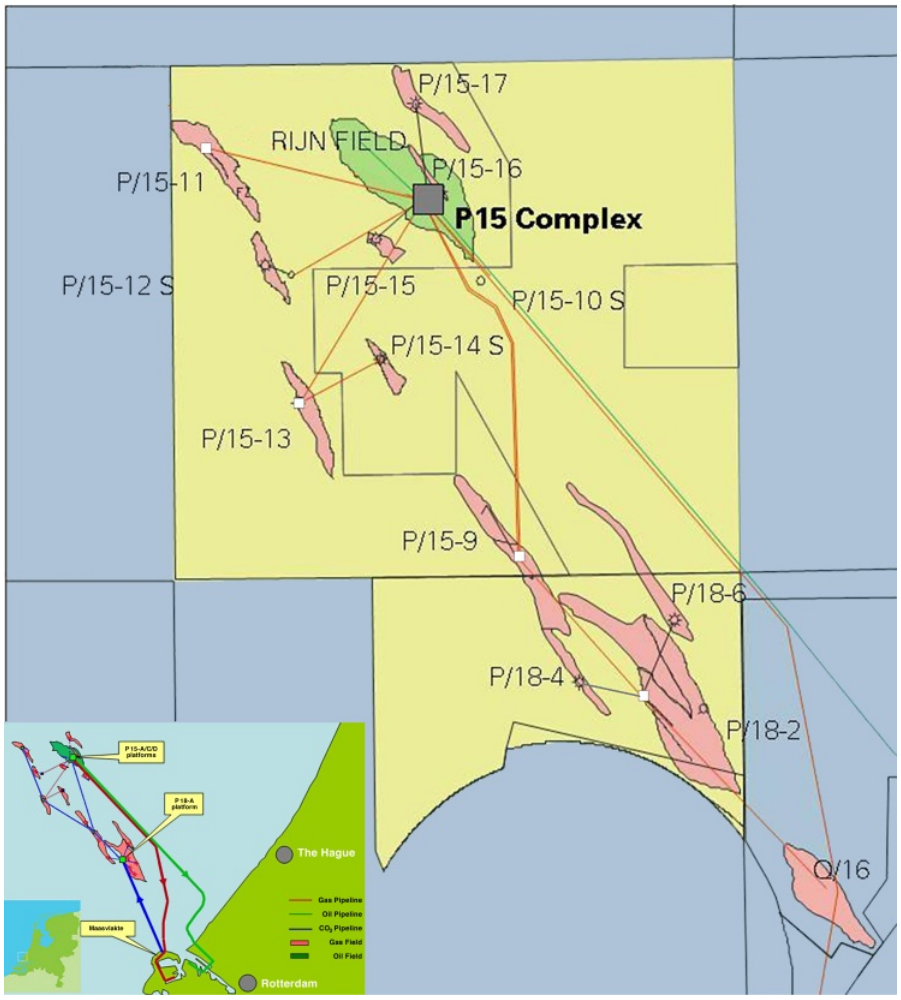

Figure 1: The location of the P18-4 and neighbouring gas fields (Courtesy of TAQA Offshore B.V.)

After agreeing with the ROAD Project[8] operators, E.ON Benelux and GDF Suez (now ENGIE Energie Nederland), to act as a CO_2 storage operator, in 2010 TAQA applied for a storage permit under the Dutch Mining Act. The application documents for the CO_2 storage were updated in 2011 to reflect changes in the Dutch Mining Act brought about by the transposition of the EU Directive of the geological storage of carbon dioxide (2009/31/EC).

Due to the steep fall in the price of emitting CO_2 under the European Union Emission Trading Scheme in 2009/2010, with the detrimental effect this has had on low carbon investments in industry, the ROAD Project has suffered severe delays from the original planned operational start of 2015. Despite this, TAQA received an irrevocable storage permit for P18-4 in September 2013. To achieve this, the operators have complied with spatial planning, environmental impact assessments, public participation requirements and the mining law.

Copies of all the applications and decisions made by the National Authority(mostly in Dutch), the final storage permit (Dutch/English) and the European Commission opinion on the storage permit (English) can be downloaded here.

[8] The ROAD Project is a planned post-combustion capture unit on a coal-fired power plant in the Rotterdam habour, capable of capturing 1.1 Mton CO_2 per annum (equivalent of decarbonizing 250 MWe coal-fired power production).

2 Project strategy

This section outlines the objective of the project, the approach, and any pre-determined limitations to the scope of work that has been completed.

2.1 Objectives

The objective of this project has been to assess to what extent the proposed P18-4 storage site, originally part of the ROAD CCS Project, complies with the 2012 Specific Guidelines for disposal of CO_2 that have been agreed upon by the Parties of the London Protocol in 2007.

2.1.1 Added value

A comprehensive evaluation of the compliance of the P18-4 storage site with the requirements of the London Protocol has not been previously completed. The outcomes of this project can help inform the debate on the robustness of the regulatory framework for CCS, and the presence of overlap or gaps across relevant national, European and international legislation.

2.2 Approach

This short project employs a simple, but systematic cross-check of the requirements of the "2012 Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations" against the content of the "Supplement to the Application for a CO_2 Storage Permit in P18-4".[9].

The application for the CO_2 storage permit is a 643 page document primarily written in Dutch. The document contains the leading scientific information submitted by the storage operator, TAQA Offshore B.V., for examination by both Dutch national regulators (The Ministry of Economic Affairs) and the European Commission.[10] The information submitted by the storage operator has been compiled to meet the requirements of the Dutch Mining Law[11] on CO_2 storage, which comprises the requirements of the EU Directive on the geological storage of carbon dioxide (2009/31/EC)[12].

Based on the information contained in the application, the National Authorityhas adjudged that both TAQA Offshore B.V. and P18-4 are in compliance with the requirements on the Dutch Mining Law with regards to CO_2 storage and issued an irrevocable storage permit in 2013.

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[9] In Dutch – "Aanvulling op de Aanvraag CO_2 Opslagvergunning P18-4".
[10] This document can be downloaded here.
[11] The Dutch Mining Law includes the Mining Act (2003), the Mining Decree (2003) and the Mining Regulation (2003). English versions (with no legal status) can be accessed here.
[12] Henceforth to be referred to as the EU CCS Directive

2.2.1 Project components

This project has been implemented in in four sequential steps:

1. Cross-check compliance assessment of P18-4 application material with the London Protocol 2012 Specific Guidelines for CO_2 disposal
2. Report initial findings on compliance
3. Stakeholder consultation with storage operator and National Authority
4. Finalise findings for submission to IEAGHG.

The stakeholders, TAQA Offshore B.V., and the Dutch Ministry of Infrastructure and Environment, representing both the applicant and the National Authority, to ensure that the findings of the assessment are as accurate as possible.

2.3 Application material for assessment

There are 3 primary documents that are used for the assessment. As mentioned in the approach, the "Supplement to the Application for a CO_2 storage permit in P18-4", including its 3 appendices and 4 annexes form the basis for the review. The "Environmental Impact Assessment CCS Maasvlakte (ROAD-CCS): Section Storage", contains important considerations for the potential site-specific environmental effects that could be brought about by the storage activity.[13]

The third document to be reviewed is the "Application for exemption from the Flora and Fauna Act", which contains information regarding the possible environmental effects of the P18-A platform modifications (from where the CO_2 will be injected into P18-4), and the 20 km section of the offshore pipeline to transport the CO_2 from the capture unit to the platform. An overview of the documents, ancillary information, their authors and legal relevance is provided in Table 1.

Table 1: Application material to be assessed in the course of this project

Title	Author	Relevant legislation	Link
Supplement to the Application for a CO_2 Storage Permit in P18-4 (including appendices and annexes)	Royal Haskoning in commission of TAQA Offshore B.V. (2011) pp.1-643	Dutch Mining Act	Here
- Appendix 1. Feasibility study P18	CATO-2 Dutch research programme on CCS (2010)	Dutch Mining Act	
- Appendix 2. History and description of the P18 fields	PanTerra Geoconsultants B.V. (2011)	Dutch Mining Act	
- Appendix 3. Fault integrity study	TAQA Offshore B.V (2011)	Dutch Mining Act	

[13] The EIA for storage is limited to the effects from CO_2 injection/storage and not from the platform or transport infrastructure.

- Annex 1. Risk management plan	Royal Haskoning in commission of TAQA Offshore B.V. (2011)	Dutch Mining Act	
- Annex 2. Plan for corrective measures	Royal Haskoning in commission of TAQA Offshore B.V. (2011)	Dutch Mining Act	
- Annex 3. Initial plan for closure	Royal Haskoning in commission of TAQA Offshore B.V. (2011)	Dutch Mining Act	
- Annex 4. Monitoring plan – including overview of logging and monitoring tools, well integrity assessment P15-9 field, Flow assurance study	Royal Haskoning in commission of TAQA Offshore B.V. (2011) / Well Engineering Partners B.V. / TNO Technical Sciences	Dutch Mining Act	
Environmental Impact Assessment CCS Maasvlakte (ROAD-CCS): Section storage	Royal Haskoning in commission of Maasvlakte CCS Project CV. (2011) pp. 1-404.	Decision on Environmental Impact Assessments 1994	Here
Application for Exemption from the Flora and Fauna Act	TAQA Offshore B.V. (2011) pp. 1-74	Flora and Fauna Act	Here

2.4 Project outputs

The project outputs are twofold. Given the vast amount of information to be assessed (over 1100 pages) and the necessity to provide clear evidence by linking the requirements of the Specific Guidelines to the application material, a spreadsheet has been used to document and organise the initial findings. The spreadsheet contains references to the sections of material that are considered relevant to the requirements of the LP.

The primary output, this report, provides the results of the assessment in a less granulated manner than in the spreadsheet. In the interest of readability, certain parts of the Specific Guidelines have been summarised in order to provide an accurate but concise description of their content.

2.5 Limitations

The findings of this project have been restricted to identifying the presence of information, as submitted in the P18-4 storage application, which could be used by a Contracting Party of the LP to consider the CO_2 stream for disposal, through the application of the 2012 Specific Guidelines. Whereas information deemed relevant will be assessed for completeness, it will not be reviewed scientifically.

It is assumed, that the requirements of Annex II of the LP, are fully incorporated into the contents and coverage of 2012 Specific Guidelines, whereby the latter can be

considered the technical leading document, and will be the leading document for the cross-check against the contents of the P18-4 permit application.

The “Risk Assessment and Management Framework for CO_2 Sequestration in Sub-Seabed Geological Structures” (RAMF) is considered supplementary to the 2012 Specific Guidelines and has not be used directly in the compliance assessment of P18-4 with the LP.

3 Overview of P18-4 application procedure

In September 2009, the ROAD CCS Project was granted financial support from the European Commission under the European Energy Programme for Recovery (EEPR). In May 2010, the project was also granted additional national support from the Dutch government. The final Environmental Impact Assessment and permit applications were submitted in June 2011. The permitting procedure for the entire ROAD Project involves a complex matrix of permitting requirements for the capture installation, the pipeline, platform and storage site, which cover all aspects of integration into built environment, interference with existing infrastructure, and an assessment of the project's impact across all environmental media. Henry et al., 2011[14], and Mozaffarian et al., 2011[15], are useful sources that outline the permitting procedure of CCS projects in the Netherlands. An overview of the legislative requirements that the ROAD CCS Project has had to comply with and their relevance for the objective of this report is provided in Table 2.

Despite the myriad of permitting requirements needed for large multifaceted infrastructures such as a CCS demonstration plant, the number of permits needed for offshore CO_2 storage operations in the Netherlands are limited in number. For storage of materials at a depth of more than 100 metres, on or offshore, a storage permit under the Dutch Mining Act is required. In 2011, the contents of the EU CCS Directive was transposed into the Mining Act, the Mining Decree and the Mining Regulation. The aforementioned legal acts therefore contain the primary conditions for the application of a CO_2 storage permit in the Netherlands. The transposition of the EU CCS Directive also enforces the mandatory requirement for Environmental Impact Assessments (EIA) on capture installations, pipelines and storage sites, through the 'Decision on Environmental Impact Assessments 1994'[16].

As required by the EU CCS Directive, the application for the storage permit was submitted to the European Commission for review in August 2011. In February 2012, the European Commission published its first Opinion on the draft storage permit, which was positive and asked for minor confirmations. The scope of the Commission's Opinion was however limited to the draft storage permit, and not the proposed monitoring plan, risk management plan, corrective measures and post-closure plans. The plans were not considered mature enough to be operational at the point of submission. The plans were written in as complete a form as possible, but the Front End Engineering and Design (FEED) had not yet been conducted. The Dutch government has assured the Commission that operational plans will be submitted to the Commission for review prior to injection.

[14] Henry, X., Jonker, T., Schoonwater, A. and Wattenberg, V. 2011. The permitting process Special report to the Global Carbon Capture and Storage Institute. Maasvlakte CCS Project C.V., Schiedam, The Netherlands. Accessed (27.02.2016): http://www.globalccsinstitute.com/sites/www.globalccsinstitute.com/files/publications/27686/road-special-report-permitting-process-final-opt.pdf

[15] Mozaffarian, H., van Horssen, A., Lako, P., Meindertsma, W. and Stortelder, B. 2011. Permitting needs for CCS operations in the Netherlands. CATO2-WP4.2-D04. Accessed (27.02.2016): http://www.co2-cato.org/publications/library1/permitting-needs-for-ccs-operations-in-the-netherlands

[16] In Dutch, Besluit milieueffectrapportage 1994, C 8.2.

The final irrevocable storage permit was provided to TAQA in September 2013. Despite the storage permit being irrevocable, the above mentioned plans must be agreed and in place, as well as a financial security being made available, prior to the start of injection, in accordance with the Dutch Mining Act. An English translated version of the permit can be found in Annex I of this document.

Table 2: Legislative requirements for the ROAD CCS Project (columns highlighted dark green indicate primary importance, and light green for secondary importance for this current assessment). * The proponent is the Maasvlakte CCS Project C.V.

Legislative requirement	Law	National Authority	Applicant
Environmental Impact Assessment (Capture, Transport, Platform, Storage)	Environmental Protection Act	Ministry of Economic Affairs, Agriculture and Innovation and the Ministry of Infrastructure and Environment; Province of Zuid-Holland (delegated to DCMR (Environmental Protection Agency for the Rotterdam Area))	Proponent*
Emission permits (for capture, transport and storage); Environmental Permission; Building Permission	Environmental Protection Act	Dutch Emission Authority	Proponent
All-in-one permit for physical aspects (Capture, Transport)	General Environmental Conditions Act	Province of Zuid-Holland (delegated to DCMR (Environmental Protection Agency for the Rotterdam Area))	Proponent
Natural Protection Act Permit	Nature Protection Act 1998	Province of Zuid-Holland	Proponent
Water Permit	Water Act	Ministry of Infrastructure and Environment (delegated to the State Water Authority, Department South Holland)	Proponent
State Zoning Plan	Spatial Planning Act	Ministry of Economic Affairs, Agriculture and Innovation and the Ministry of Infrastructure and Environment	Ministry of Economic Affairs, Agriculture and Innovation and the Ministry of Infrastructure and Environment
Water Permit	Water Act	Ministry of Infrastructure and Environment (delegated to the State Water Authority, Department Zuid-Holland)	Proponent
Railway Permit	Railway Act	ProRail	Proponent
Flora and Fauna Act Exemption	Flora and Fauna Act	Ministry of Economic Affairs, Agriculture and Innovation	Proponent
All-in-one permit for physical aspects (Platform modifications)	General Environmental Conditions Act	Ministry of Economic Affairs, Agriculture and Innovation	TAQA
Storage Permit	Mining Act	Ministry of Economic Affairs, Agriculture and Innovation	TAQA

4 Overview of the "Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations"

The inclusion of CO_2 streams onto the reverse list of the London Protocol in February 2007, triggered the establishment of the CO_2 Working Group by the London Protocol Scientific Group. The CO_2 Working Group was tasked with the development of a set of guidelines which could support the relevant authorities of LP Parties to consistently enforce the requirements of Annex II of the LP. In November 2007, the "Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations"[17] were adopted by the Parties to the LP. In 2012 the Specific Guidelines were amended to include some additions on transboundary storage and/or movement of CO_2, and the confirmation of the application of these guidelines for projects involving the storage of CO_2 exported from foreign countries.

The Specific Guidelines has been developed to:

"deal with risks posed by carbon dioxide sequestration in sub-seabed geological formations over all timescales and primarily at the local and regional scale and thus focus on the potential effects on the marine environment in the proximity of the receiving formations."

The "risks" associated with carbon dioxide sequestration in sub-seabed geological formations are defined as those associated with the leakage of CO_2, but also any other substances present in the gas stream or substances which have been mobilised by the gas stream in the subsurface.

The Specific Guidelines are structured as follows:

1. Introduction
2. Waste prevention audit
3. Consideration of waste management options
4. Chemical and physical properties
5. Action list
6. Site selection and characterisation
    a. Characterization of the sub-seabed geological formation
    b. Characterization of the marine area under consideration
    c. Evaluation of potential exposure
7. Assessment of potential effects
    a. Evaluation of potential effects
    b. Risk assessment
    c. Impact hypothesis
8. Monitoring and risk management
    a. Mitigation or remediation plan
9. Permit and permit conditions

[17] The term "Specific Guidelines" will be used for the remainder of this document.

The structure of the Specific Guidelines has been adopted as a basis upon which the assessment of the P18-4 permit application documents has been completed.

5 Compliance assessment

5.1 Reader guide

Connecting the vast amount of information contained within P18-4 application documents and relevant EIA reports with the requirements of the Specific Guidelines and communicating these results in a concise report format presents clear challenges. The full systematic assessment has been documented in spreadsheet format, whereby the individual requirements of each paragraph of the Specific Guidelines are assessed against the application material. Furthermore, the spreadsheet includes references to the precise sections and page numbers of relevant information contained with the application documents in order to allow the outcomes of this assessment to be validated by third-parties.

This section provides the results of the assessment in a less granulated manner than in the spreadsheet. In the interest of readability, certain parts of the Specific Guidelines have been summarised, in order to provide an accurate but concise description of their content. The requirements are numbered according to the relevant paragraphs in the Specific Guidelines. A number of paragraphs containing more descriptive content rather than direct requirements have been omitted from this assessment, but are covered in the spreadsheet.

5.1.1 Definitions and assessment criteria

For the intent and purpose of this assessment, the definition of 'compliance' is as follows:

"In the application material submitted by the applicant, TAQA Offshore B.V., to the national authority charged with the granting of CO_2 storage permits, 'The Dutch Ministry of Foreign Affairs', sufficient information has been provided to allow the national authority to evaluate whether the planned CO_2 storage activities can be implemented in a manner consistent with the provisions of the 1996 London Protocol."

Each Specific Guideline requirement will be evaluated with a simple criteria provided in Table 3.

Table 3: Evaluation criteria for the assessment

	Sufficient information is provided
	Information or justification is partially sufficient but may require further clarification
	Insufficient information is provided

To support the evaluation of each Specific Guideline requirement, a short summary of the submitted information will be provided. Furthermore, relevant references to where the Specific Guideline requirement is addressed in the final storage permit are

provided. The latter allows an assessment of not only whether sufficient information has been provided, but that also the eventual permitting by the National Authority has been developed in a manner consistent with the 1996 London Protocol.

5.2 Non-assessed sections of the Specific Guidelines

5.2.1 Introduction

The introduction to the Specific Guidelines provide the overall objective of the document and places it in the legal framework of the London Protocol and particularly the documents purpose with regards to Annex I and II of the Protocol. The introduction section of the Specific Guidelines contain no exact requirements for permit applications, and therefore this section has not been assessed further.

5.2.2 Waste prevention audit

Section 2 of the Specific Guidelines concerns whether opportunities exist for waste prevention at source, rather than the dumping of waste. It is stated in the Specific Guidelines that this section is not directly pertinent to the disposal of carbon dioxide streams. The obligation of the London Protocol to reduce the need for disposal should be considered in the context of approaches to reducing greenhouse gas emissions and mitigating climate emissions. Given that CO_2 sequestration would be a generally unavoidable element of a carbon capture and storage project, it seems justified that a waste prevention audit is not directly applicable.

5.3 Consideration of waste management options

5.3.1 Assessment overview

Section 3 states that applications for the disposal of CO_2 streams from capture processes for sequestration into sub-seabed geological formations should demonstrate consideration for:

Table 4: Assessment overview for Section 3 – Consideration of waste management options

Para	Specific Guideline requirements	Evaluation
3.2.1	*the incidental associated substances in the carbon dioxide stream and, if necessary, options for treatment to reduce or remove those substances;*	
3.2.2	*other disposal and/or sequestration options, e.g. land-based underground storage.*	

The LP also identifies reuse and off-site recycling as options to be considered in this context. However, the Specific Guidelines state that such options are not directly pertinent to the disposal of CO_2 streams into sub-seabed geological formations.

5.3.2 Evaluation and summary of information submitted

Paragraph 3.2.1 - The information provided by the applicant would be deemed to be sufficient for a positive assessment of requirement 3.a. The CO_2 stream from the ROAD post-combustion capture installation is 99.9% pure. The remaining 0.1% is composed of incidental associated substances from the capture installation. It is expected that the CO_2 stream is not corrosive, the oxygen concentration is 40 ppm or less, and there is no H_2S (0 ppm). The CO_2 will also be dry, meaning that there is 50 ppm or less water in the CO_2 stream.

Paragraph 3.2.2 - Within the Environmental Impact Assessment of the CO_2 storage in P18-4, alternative offshore locations also with the P18 block are assessed for their suitability. There is no assessment of onshore storage opportunities contained in the permit application.

5.3.3 Reference in the final storage permit

Paragraph 14, subsection m. of the final storage permit states:

"The CO_2 that is stored will originate from MPP3 (E. ON's coal plant) in the Maasvlakte area; the composition of the CO_2 stream as stated in the application meets the requirements imposed by law. Because the possibility cannot be excluded that CO_2 from another source will be stored, the permit provides that the permit holder will be obliged to notify the Minister of Economic Affairs of any significant change in the composition of the CO_2 stream and will be obliged to demonstrate that the safety and integrity of the system and the storage process have not been compromised and do not present any significant risk to public health or the environment."

5.4 Chemical and physical properties

5.4.1 Assessment overview

Section 4 concerns the characterisation of the CO_2 stream. The CO_2 stream should be sufficiently characterised to enable a proper assessment of the potential impacts on human health and the environment. This analysis should include as appropriate:

Table 5: Assessment overview for Section 4 – Chemical and physical properties

Para	Specific Guideline requirements	Evaluation
4.2.1	*origin, amount, form and composition;*	
4.2.2	*properties: physical and chemical; and*	
4.2.3	*toxicity, persistence, potential for bio-accumulation*	

5.4.2 Evaluation and summary of information submitted

Paragraph 4.2.1 - The CO_2 stream from the ROAD post-combustion capture installation and the permit application is for a maximum of 8.1 Mton. From the ROAD project, a minimum of 4 Mton and a maximum of 7.5 Mton will be delivered between 2015 and 2019, consistent with an injection rate of 47.56 kg CO_2/sec. The CO_2 from ROAD is 99.9% pure. The remaining 0.1% is composed of incidental associated substances from the capture installation, see Table 6. For CO_2 streams that are not

sourced from the ROAD project, these will only be accepted on the condition that the stream is overwhelmingly CO_2 and cannot damage the integrity of the storage site.

Table 6: Maximum levels of impurities in the CO_2 stream from the ROAD capture installation under standard operating conditions (Veltin & Belfroid, 2011[18])

Substance	N_2	O_2	H_2O	Acetaldehyde	Ar
Amount	350 ppmv	40 ppmv	40 ppmv	10 ppmv	7 ppmv

Paragraph 4.2.2 – The CO_2 will be injected from the P18-A platform into the P18-4 reservoir at pressures determined by the in-situ reservoir pressure. The physical characteristics of the CO_2 will be governed by the thermodynamic behaviour of the stream, which is controlled by the reservoir pressure, the injection rate and surface temperature. At the start of injection, the low in-situ reservoir pressure (20 bar) means that the CO_2 can be injected as a gas. As the formation is filled, the injection pressure must be increased. During the injection period, the increasing reservoir pressure will result in the state of CO_2 changing from gaseous during the first phase of injection to liquid until the reservoir is full.

Paragraph 4.2.3 – The risk assessment conducted with the storage permit states that the risk of CO_2 leaking to the biosphere is negligible. Therefore the application material does not comment on toxicity, persistence or potential for bio-accumulation of the CO_2 or incidental substances (impurities) contained in the stream.

5.4.3 Reference in final storage permit

Paragraph 14, subsection e. of the final storage permit states:

"The volume of CO_2 that may be stored will be determined by the maximum permissible pressure in the reservoir. TAQA calculates the reservoir's capacity to be 8.1 Mton CO_2. The maximum permissible CO_2 injection rates and pressure and the maximum permissible pressure of the stored CO_2; TAQA states a maximum supply capacity of 1.5 Mton per year; this is consistent with an injection rate of 47.56 kg CO_2/sec. The injection pressure may not exceed the initial pressure upon commencement of natural gas extraction from the P18-4 reservoir (348.5 bar)."

See sub-section 5.3.3 for the reference to the source and legal composition of the CO_2 stream.

5.5 Action list

5.5.1 Assessment overview

Section 5 of the Specific Guidelines concerns the development of an 'Action List', which provides a screening mechanism for determining whether a material is considered acceptable for dumping. For CO_2 streams, each Party to the LP should develop a screening tool to assess the suitability of CO_2 streams for disposal, based

[18] Veltin, J. and Belfroid, S. 2011. Maasvlakte CO_2 storage project "ROAD" Flow Assurance Study. TNO RPT-DTS 2011-01149. TNO, The Netherlands.

on the presence of incidental substances. Furthermore the section reaffirms the definition of CO_2 streams and prohibits the addition of wastes or other matter for the purposes of disposal.

Table 7: Assessment overview for Section 5 – Action List

Para	Specific Guideline requirements	Evaluation
5.2	*Development of a screening tool to assess the acceptability of CO_2 streams for disposal, based on the presence of incidental substances*	
5.4	*Carbon dioxide streams must consist overwhelmingly of carbon dioxide*	
5.5	*No wastes or other matter may be added for the purpose of disposing of those wastes or other matter*	

5.5.2 Evaluation and summary of information submitted

Paragraph 5.2 – The responsibility of the development of the Action List lies with the National Authority. It cannot be determined from the publicly available information on the application procedure whether a screening tool for CO_2 streams has been developed. Given that only one CO_2 storage permit has been applied for, which accepts only one source, it would not seem necessary or appropriate to define a screening tool to assess acceptability of different CO_2 streams. Should CCS become more prevalent, with different CO_2 sources and capture systems, such a screening tool could be warranted. As stated in section 5.3.3, paragraph 14, subsection m., the final permit does oblige the permit holder to inform the Dutch Ministry of Economic Affairs of any change in the composition of the CO_2, of any source.

Paragraph 5.4 – The CO_2 source consists overwhelmingly of CO_2.

Paragraph 5.5 – No wastes will be added to the CO_2 stream.

5.5.3 Reference in final storage permit

Section – Grounds for refusal, paragraph 11 of the final storage permit states:

"Pursuant to Section 27(1)(h) of the Mining Act, a storage permit can be refused if public interests require the area that is the subject of the storage permit application to be used for storing substances other than those listed in the application. No such interest in the storage of substances other than CO_2 has been shown to exist and there are no indications that the P18-4 storage reservoir will be needed for other substances in the near future."

5.6 Site selection and characterisation

Section 6 is divided into three separate sections:

i. Characterization of the sub-seabed geological formation
ii. Characterization of the marine area under consideration
iii. Evaluation of potential exposure

Characterization of the sub-seabed geological formation

5.6.1 Assessment overview

Section 6 of the Specific Guidelines states that information needed for the selection of a sub-seabed geological formation includes a geological assessment based on a characterization of the site. The section provides a list of important considerations, of which the P18-4 application material has been screened for the inclusion of such information.

Table 8: Assessment overview for Section 6.i – Characterisation of the sub-seabed geological formation

Para	Specific Guideline requirements	Evaluation
6.2.1	*Water depth and injection storage depth*	
6.2.2	*storage capacity, injectivity and permeability of the geological formation;*	
6.2.3	*long-term storage integrity of the geological formation;*	
6.2.4	*the surrounding geology, including the tectonic setting;*	
6.2.5	*potential migration and leakage pathways over time, and potential effects to the marine environment of leakage of CO_2*	
6.2.6	*potential interactions of the injected carbon dioxide stream with the geological formation and the impacts on the relevant infrastructures and the surrounding geology, including potential mobilization of hazardous substances;*	
6.2.7	*possibilities for monitoring*	
6.2.8	*mitigation and remediation possibilities*	
6.2.9	*economic and operational feasibility*	

5.6.2 Evaluation and summary of information submitted

Paragraph 6.2.1 - Assuming water depth as a definition between the atmosphere and the sea-bed, the depth of the top of the first stratigraphic layer "Upper North Sea Group, NU" is stated as 33.5 mTVDss (metres true vertical depth sub-sea). The CO_2 will be injected through P18-4A2 well. The depth of the well casing perforations, through which the CO_2 will enter the storage formation, are between 3195 and 3303 mTVDss. The top of the P18-4 reservoir is 3220 mTVDss, which has a thickness of approximately 200 m.

Paragraph 6.2.2 - The storage capacity of the P18-4 reservoir has been determined based on the information collected during gas production. Based on the knowledge of the geological characteristics of the formation and pressure data at the start and during production, a maximum storage capacity has been derived. However, a number of practical variables must be considered in determining the actual storage

capacity. The total storage capacity is expected to be 8.8 Mton; however, this will not be realised due to the fact that there will be some residual gas in the reservoir, as the pressure has been reduced to approximately 20 bar. This means that a portion of the reservoir volume will not be filled with CO_2. The initial reservoir pressure was 348.5 bar, but as a risk management procedure, the reservoir will only be injected with CO_2 until the reservoir pressure reaches a maximum of approximately 320 bar. Given these practical restrictions stated above, it is expected that approximately 8.1 Mton CO_2 can be stored. It should be mentioned that the total amount of CO_2 injected will be dependent on reaching the maximum reservoir pressure.

The applicant states a maximum CO_2 supply capability of 1.5 Mton per year, which equates to approximately 47 kg/s. Based on the known porosity and permeability of the P18-4 reservoir, reservoir simulation studies indicate that injecting the CO_2 at a rate of 47 kg/s to a total of 8.1 Mton is possible. The geological formation into which the CO_2 will be injected comprises a Triassic reservoir interval about 200 meters thick, made up of the Hardegsen, Upper Detfurth, Lower Detfurth, and Volpriehausen rock layers. The respective permeabilities of the 4 layers are 207.0, 0.8, 0.1 and <0.1.

Paragraph 6.2.3 - The P18-4 reservoir comprises a Triassic reservoir interval about 200 meters thick, made up of the Hardegsen, Upper Detfurth, Lower Detfurth, and Volpriehausen rock layers. The Hardegsen rock layer has a high permeability of 207 mD which is highly suitable for the injection of CO_2. The P18-4 reservoir is entirely surrounded by faults that act in this case as structural trap. The reservoir is overlaid by an extensive cap rock of about 150 to 180 meters thickness represented by Triassic age layers with variable lithology consisting of impermeable claystones, siltstones, evaporites and dolostones. This primary top seal directly overlies the reservoir and is known to have been an effective seal for the P18-4 gas field. Above the primary top seal, there is approximately 500 meters Jurassic-age clays, which could also be considered part of the primary top seal.

Paragraph 6.2.4 - The application uses the definition of a 'storage complex' from the EU CCS Directive. The storage complex is defined not only as the immediate surrounding geology in direct contact with the storage formation, but also the further surrounding geology whereby the presence of CO_2 is undesirable but also unexpected. The presence of CO_2 in any part of the storage complex does not indicate any immediate environmental or safety risks. The storage complex is defined as: The storage formation of P18-4 and the adjacent P15-9, and all the geological layers above the storage formation to the basis of the Chalk Group, consisting of the Upper Germanic Triassic Group, Altena Group, Schieland Group, Rijnland Group, and aquifer intervals Rijn/Rijswijk sandstone, Holland Greensand, and Texel Greensand. It includes the formations below the P18-4 and P15-9 reservoirs, consisting of Rogenstein and Main Claystone as well as the fault zones around storage site P18-4.

The P15-9 reservoir is located adjacent to P18-4 at the same depth, and the two reservoirs are understood to be full isolated by a fault. An integrity study using fault reactivation tool and seismic imaging showed there is possibly a small amount of juxtaposition between reservoirs, and therefore the possibility that CO_2 will migrate from P18-4 to P15-9 over geological time cannot be excluded. Both reservoirs have the same type of cap rock meaning that if migration should occur, this does not increase the risk of leakage out of the storage complex.

Paragraph 6.2.5 - The possibility of migration and leakage pathways are fully evaluated in using a 10-step risk assessment plan. The CATO[19] 200-page P18-4 Feasibility Study, which has assessed reservoir geology, cap rock integrity, fault integrity, well integrity, geochemical and geomechanical modelling, and dynamic reservoir modelling, is used as a basis to inform the risk assessment plan.

The potential effects to the marine environment of leakage of CO_2 are considered in the Environmental Impact Assessment (EIA) report for CO_2 storage. In this document the mechanical, thermal and chemical impacts of the CO_2 on the storage formation are evaluated. The potential impacts of CO_2 injection on the overlaying geology and the biosphere above P18-4 are also evaluated. Through the EIA, it has been concluded that the risk to the biosphere is restricted to possible surface elevation during the injection of CO_2. The risks of CO_2 leaking into the marine environment are considered negligible, and therefore no assessment of CO_2 leakage is provided.

Paragraph 6.2.6 - The potential chemical reactions of the CO_2 on the short, middle and long term are mentioned in the permit application, and the evaluator is referred to the Geochemical modelling work in Section 5 of the CATO P18-4 Feasibility Study. This work concludes that based on the expected CO_2 stream, chemical reactions can occur on a short, middle and long term, however they form no risk to cap rock integrity. No migration pathways are expected to form on the short or long timeframes.

Paragraph 6.2.7 - Options for a monitoring plan are outlined by the applicant, and possible restrictions of certain techniques are mentioned. For example, 3D seismic could be used for CO_2 plume imaging; however, given the depth of the field this is not considered as suitable for P18-4. Downhole and pressure/temperature monitoring are stated as likely tools. The full monitoring plan was not submitted at the time of application, but a finalised version is required to be submitted to the National Authority and approved, prior to the commencement of injection.

Paragraph 6.2.8 - An initial remediation plan is provided by the applicant. Leading from the risk assessment, 6 possible undesirable occurrences, related effects and identified remediation actions are provided. A full remediation plan was not submitted at the time of application, but a finalised version is required to be submitted to the National Authority and approved, prior to the commencement of injection.

Paragraph 6.2.9 - With regards to economic feasibility, the applicant has provided information to prove financial soundness of the operational entity to undertake the project. There is also an overview of the financial securities to be paid in accordance with the EU CCS Directive. There are no further references regarding economic feasibility in the application. There is also no explicit mention of operational feasibility in the application documents.

5.6.3 Reference in final storage permit

[19] CATO is the National Dutch Research Programme on CCS, a consortium of academic, research and industrial parties. Between 2009-2014, the CATO2 programme had a total funding budget of €60 million.

A considerable part of the final storage permit concerns the suitability of the P18-4 formation as a CO_2 sequestration site. It is not practical to repeat all this information here, instead an overview of relevant sections and paragraphs is listed:

- Section - Grounds for refusal, paragraph 2.
- Section - Grounds for refusal, paragraph 7.
- Section - Grounds for refusal, paragraph 13.
- Section – Permit requirements, paragraph 14, subsections b., c., h. - k.

The English translated version of the final permit can be found in Annex I, however the original Dutch version takes precedence.

Characterization of the marine area under consideration

5.6.4 Assessment overview

The second subsection of Section 6 concerns the characterisation of the marine area under construction. Here information should be given about location of amenities, values and other uses of the sea in the area under consideration, including the injection and storage site, transport infrastructure, where relevant, and the surrounding potentially affected area. This will include physical, hydrological, hydro-dynamical, chemical and biological characteristics of the water-column and the seabed.

Table 9: Assessment overview for Section 6.ii – Characterisation of the marine area under consideration

Para	Specific Guideline requirements	Evaluation
6.7.1	*coastal and marine areas of environmental, scientific, cultural or historical importance*	
6.7.2	*fishing and mariculture areas*	
6.7.3	*spawning, nursery and recruitment areas*	
6.7.4	*migration routes*	
6.7.5	*seasonal and critical habitats*	
6.7.6	*shipping lanes*	
6.7.7	*military exclusion zones*	
6.7.8	*engineering uses of the seafloor, including mining, undersea cables, desalination or energy conversion sites*	

5.6.5 Evaluation and summary of information submitted

This assessment is primarily focused on the compliance of the storage permit for P18-4 with the requirements of the London Protocol. According to Dutch Law, storage permits can only be provided at a depth of 100 metres or more from the seabed. The Dutch Mining Act therefore does not cover the characterisation of the marine area under construction.

The modifications to the P18-A platform are regulated by an Environmental Permit[20], to be provided by the Dutch Ministry of Economic Affairs. This application document covers the effects of the platform revision both in terms of environmental impacts, but also spatial planning and interaction with existing maritime activities. The document can be accessed here (in Dutch).

For the offshore section of the 25 km pipeline (approximately 20 km), a Water License[21] for the pipeline has been acquired from the Dutch Ministry of Infrastructure and the Environment. This application document covers the environmental impacts, spatial planning and interaction with existing maritime activities of the CO_2 pipeline. The application document can be accessed here (in Dutch), and the Environmental Impact Assessment for the pipeline can accessed here (in Dutch).

Both the pipeline and platform revisions have also received exemptions from the Dutch Flora and Fauna Act, due to their minimal impact on the environment. The application for these exceptions both refer to a detailed background report on the environmental impacts of the platform and pipeline. The request for exception and background report for the platform can be accessed here and for the pipeline here (in Dutch).

Evaluation of potential exposure

5.6.6 Assessment overview

The third and final subsection of Section 6 is concerned with site-specific considerations of the potential exposure pathways, and an assessment of the probabilities of leakage. A number of potential migration or leakage pathways from the sub-seabed are listed:

Table 10: Assessment overview for Section 6.iii – Evaluation of potential exposure

Para	Specific Guideline requirements	Evaluation
6.9.1	*the injection well, other abandoned or active the same geological formation*	
6.9.2	*areas where permeable rock reaches the surface of the seabed (e.g. seabed outcrop)*	
6.9.3	*transmissive fractures of, or high-permeability zones within, the cap rock*	
6.9.4	*the pore system in low-permeability cap rocks (e.g. if the capillary entry pressure at which carbon dioxide streams may enter the cap rock is exceeded) or degradation of the cap rock caused by reaction with acidified formation waters*	
6.9.5	*areas where the cap rock is locally absent*	
6.9.6	*lateral migration along the storage formation (e.g. if a storage structure is overfilled beyond the spill point).*	
6.10	*Simulation of the short- and long-term fate of stored carbon dioxide streams should be performed*	

[20] In Dutch – Omgevingsvergunning
[21] In Dutch – Watervergunning

5.6.7 Evaluation and summary of information submitted

Paragraph 6.9.1 - The P18-4 reservoir has only one well, the P18-4A2. For this well, there is some uncertainty regarding its technical state. Although it is expected that the cementing of the well is suitable for CO_2 storage operations, additional checks must be carried out, and if necessary, the cementing must be improved. This is covered in the risk management plan, and remediation and monitoring actions have been outlined. The risk is only during the injection phase, after which the well will be plugged with a Fullbore Formation plug.

Paragraph 6.9.2 – From the information provided on the characterisation of the storage formation, the evaluator can deduce that this is not a potential leakage pathway.

Paragraph 6.9.3 - A fault integrity study using fault reactivation tool and seismic imaging showed there is possibly a small amount of juxtaposition between reservoirs (P18-4 and P15-9; 30 meters). Due to the pressure difference and gas composition between compartments, the fault juxtaposition appears to be sealing and does not represent a significant risk factor for CO_2 plume migration between neighbouring reservoirs. Reservoir pressure data collected during the gas production phases of P18-4 and P15-9 indicates that the reservoir pressure in P15-9 was consistently lower (approx. 30 bar) than P18-4. This would support the theory of two isolated gas reservoirs, because if the two reservoirs were connected, the pressure difference would be expected to equalise as gas would move from the higher pressure P18-4 field to P15-9. Despite this scientific evidence of two separated formations, a precautionary approach has been adopted and the monitoring and remediation plan include scenarios involved the migration of CO_2 from P18-4 to P15-9.

Paragraph 6.9.4 - Management actions are stated to reduce the risk of potential leakage through the cap rock via mechanical, thermal and chemical reactions. By controlling the formation pressure, temperature and chemical composition of the injected CO_2, the risk can be considered negligible. During CO_2 injection, the formation pressure will not exceed 90% of the original formation pressure, so undesirable mechanical effects on the cap rock can be prevented. Geochemical modelling recognises that the injection of CO_2 can reduce the pH of the formation water, but the effects of this on reservoir rocks and the cap rock are negligible.

Paragraph 6.9.5 - From the information provided on the characterisation of the storage formation, the evaluator can deduce that this is not a potential leakage pathway.

Paragraph 6.9.6 - This risk is covered in the risk management plan. The P18-4 has proven to be gas tight for a specific pressure (348.5 bar). So long as this pressure is not exceeded, the risk that CO_2 will migrate from the formation is considered negligible.

Paragraph 6.10 - A dynamic model has been developed based on the historic production data and pressure readings from the reservoir. The dynamic model has been built using the MoRes program developed by Shell. This model is used to

predict the behaviour of the injected CO_2, and define operational parameters, ensuring that the planned amount of CO_2 can be stored and short and long-term timeframes.

5.6.8 Reference in final storage permit

Section – Permit requirements, paragraph 14, subsection c, states:

"The P18-4 reservoir is an independent reservoir. Storage in the reservoir will not transmit pressure to any area outside the storage reservoir. The reservoir does not form part of a hydraulic unit;"

Section – Permit requirements, paragraph 14, subsection d, states:

"It is essential to the storage process that adjustments for CO_2 injection are made to the P18-A mining equipment and the P18-4A2 well before the injection is made."

Section – Permit requirements, paragraph 14, subsection f, states:

"The pressure limits of the stored CO_2; TAQA's application states that the reservoir pressure limit is 320 bar. This value is below the reservoir's initial pressure of 348.5 bar when gas extraction was commenced. TNO and SodM advised ensuring that the pressure in the P18-4 reservoir does not exceed the initial pressure, either before or after the injection period."

5.7 Assessment of potential effects

Section 7 is divided into three separate sections:

i. Evaluation of potential effects
ii. Risk assessment
iii. Impact hypothesis

Evaluation of potential effects

5.7.1 Assessment overview

Section 7 of the Specific Guidelines require an assessment of the risks posed by a leak from the CO_2 sequestration process. The assessment should primarily consider the dissolution of CO_2 into the overlying water and sediments. The focus of the assessment should be on possible changes to marine chemistry due to high carbon dioxide levels, and the possible impacts on the metabolism of marine organisms, and also potential effects to human health. Possible effects on speciation, mobility or bio-availability of metals, nutrients and other compounds are mentioned. Particular attention should be given to sensitive ecosystems or species.

Table 11: Assessment overview for Section 7.i – Evaluation of potential effects

Para	Specific Guideline requirements	Evaluation

7.6	*Evaluation of potential effects on human health, living resources, amenities and other legitimate uses of the sea.*	

5.7.2 Summary of information submitted

The effects assessment covers the possible mechanical, chemical and thermal changes due brought about the injection of CO_2 into P18-4. However, the risk of CO_2 leakage to the marine environment (defined as 500 metres below sea-level to the surface of the sea) has not been identified as a potential risk. The only risk to the biosphere identified is a possible risk of surface elevation, which would offset the surface subsidence due to historic gas production above P18-4. No worse case scenarios of CO_2 reaching the biosphere are mentioned, and therefore no effects assessment of CO_2 on living resources has been included.

5.7.3 Reference in final storage permit

Section – Grounds for refusal, paragraph 13, states:

"Pursuant to Section 27(3) of the Mining Act, the permit can be refused if storage under the proposed operating conditions would entail a significant risk of leakage or significant environmental or health risks…TNO and SodM opinions of 23 November 2010, 25 November 2010, and 2 August 2011 indicate that there is an extremely small risk that there would be leakage between the storage reservoir and the areas over, under, and near the reservoir or through well P18-4A2, the only well that has been drilled in the P18-4 reservoir...Given the limited chance of migration and leakage described above, and the fact that, should migration occur, both reservoirs will continue to meet safety requirements, there is no reason for refusing the permit based on Section 27(3)."

Risk assessment

5.7.4 Assessment overview

According to the Specific Guidelines, the risk assessment should be described in terms of the likelihood of exposure, for example the leakage of the CO_2 streams and the associated effects on habitats, processes, species, communities and uses. Emphasis is required to be placed on biological effects and habitat modification, as well as physical and chemical change. No risk assessment methodology is suggested, although a number of specific factors should be considered:

Table 12: Assessment overview for Section 7.ii – Risk assessment

Para	Specific Guideline requirements	Evaluation
7.7	The risks should be sufficiently described or quantified so that it is clear what variables should be assessed during monitoring	
7.8.1	Magnitude to which the release increase the concentration of the substance in the seawater, sediments or biota	

7.8.2	The degree to which the substance can produce adverse effects on the marine environment or human health	

5.7.5 Summary of information submitted

Paragraph 7.7 - The application material states that the standard procedure for risk calculation is conducted through a Quantitative Risk Assessment (QRA), where in the basis of established risk profiles, the magnitude of a risk can be derived and can be considered as acceptable or not. For CO_2 storage, there is insufficient experience and data available on the probabilities of unexpected consequences to perform a QRA.

The applicant has adopted the so-called bow-tie methodology, to quantitatively assess the risks. Hereby the relevant studies both specific to P18-4, combined with general expertise on CO_2 storage and oil and gas production, are reviewed during expert workshops to identify potential risks and their consequences. A visual interpretation of the bow-tie methodology is presented in Figure 2 .

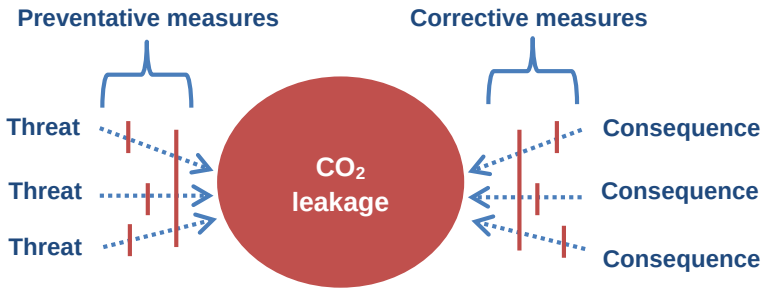


Figure 2: The bow-tie risk assessment methodology as presented by the applicant

The expert judgement workshop led to the identification of four possible scenarios upon which detailed assessments of the threats, probabilities, consequences, estimate of the extent of the risk, risk management, and remaining risk levels (post-management) have been developed. The four leakage scenarios, or risks, are:

- Leakage through the cap rock
- Leakage via a spillpoint
- Leakage through fractures
- Leakage through well

The leakage scenarios are then individually assessed and the results of which are placed onto a risk matrix. A risk matrix is a valuable method for visualising the presence of risks, and for deciding which risks are acceptable and which are not. Any migration of CO_2 from out of the storage complex is an undesirable consequence. All risks that could lead to CO_2 migrating from the storage complex must be classified as low, but preferably as negligible prior to the start of injection.

The completed risk matrix for the P18-4 proposed storage site as submitted by the applicant is provided in Figure 3. The matrix classifies both the probability of occurrence and the potential consequences of leakage through the cap rock,

spillpoint and fractures as negligible. Leakage through the well P18-4A2 is classified as having a medium risk of occurrence with low possible consequences, due to the uncertainty of the integrity of the well cementing. After additional assessment and, if necessary, remedial measures are carried out, the probability of leakage will be reduced to low or negligible, dependent on the outcomes of the remedial measures.

Paragraph 7.8.1/2 - In the assessment of each scenario, the risk of CO_2 leaking from the P18-4 or P15-9 formations to the marine environment is considered negligible, and therefore not assessed as a consequence. Therefore accumulation in seawater, sediments and biota, and possible related effects are not covered. It is assumed that because the applicant has stated that the risk of leakage to the marine environment is negligible, no potential effects to the environment and human health are considered for further assessment.

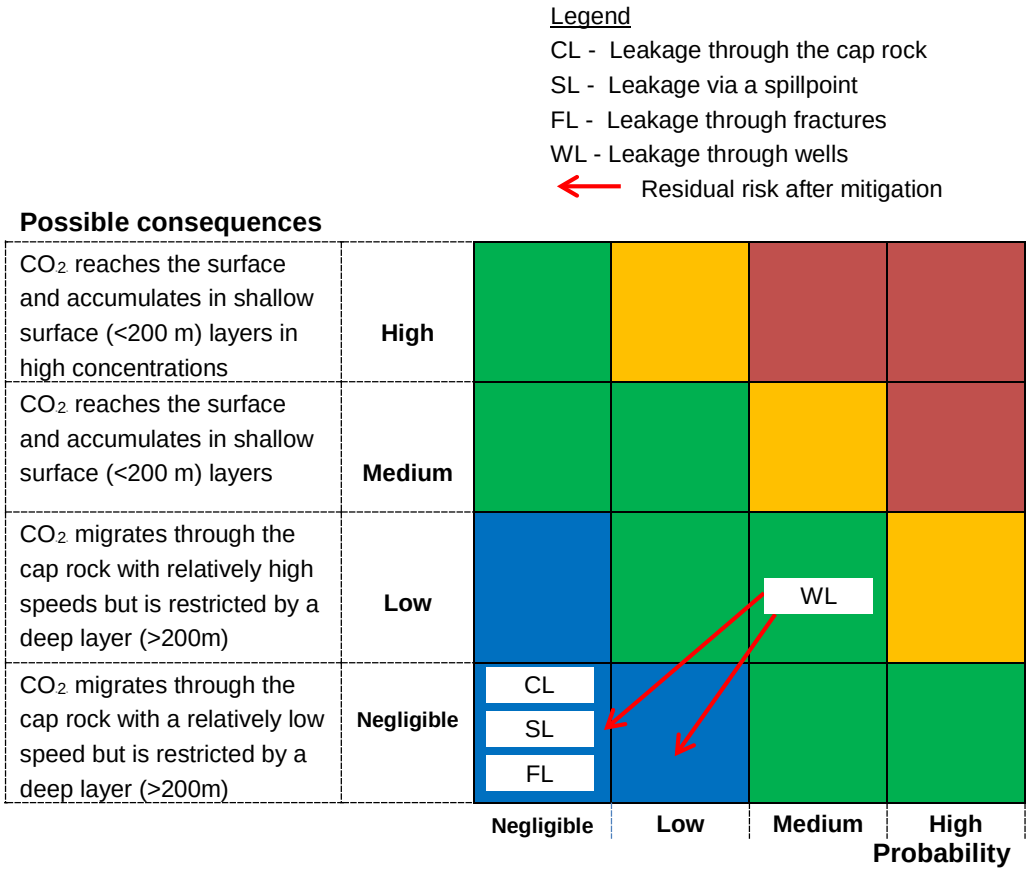


Figure 3: Risk matrix for CO_2 storage in P18-4 as submitted in the storage permit (translated from Dutch).

Impact hypothesis

5.7.6 Assessment overview

The third subsection of Section 7 refers to the development of an "Impact Hypothesis". This should be a concise statement of the expected consequences of disposal. It provides the basis for deciding whether to approve or reject the proposed disposal option and for defining environmental monitoring requirements. Key

elements in the development and testing of the Impact Hypothesis, such as preventative measures, conditions of the site and the characterisation of the CO_2 stream should be included.

Table 13: Assessment overview for Section 7.iii – Impact hypothesis

Para	Specific Guideline requirements	Evaluation
7.11	*Development of an impact hypothesis*	

5.7.7 Summary of information submitted

Paragraph 7.11 - The term “Impact Hypothesis” is not mentioned in the application material or in the final storage permit. However in both the application material and the storage permit, there are statements that could suffice meeting the requirement for a go/no-go statement. The Impact Hypothesis could, however, be interpreted as the final outcome of the risk assessment process. The Risk Matrix provided in Figure 3 provides a concise visual overview of the expected consequences of disposal and could also be considered to comply with the definition of an Impact Hypothesis.

5.8 Monitoring and risk management

Section 8 is divided into two separate sections:

i. Monitoring
ii. Mitigation or remediation plan

Monitoring

5.8.1 Assessment overview

According to the Specific Guidelines, the monitoring of the site is necessary to verify that the permit conditions are met and that assumptions made during the permit review and site selection process were correct and sufficient to protect the marine environment and human health. There are number of broad requirements that a monitoring plan must cover, including:

Table 14: Assessment overview for Section 8.i – Monitoring

Para	Specific Guideline requirements	Evaluation
8.1	Have clearly defined objectives which may then be used to trigger mitigation or remediation plans.	

In addition to the broad requirements, some more specific monitoring aspects that should be included are mentioned:

Para	Specific Guideline requirements	Evaluation

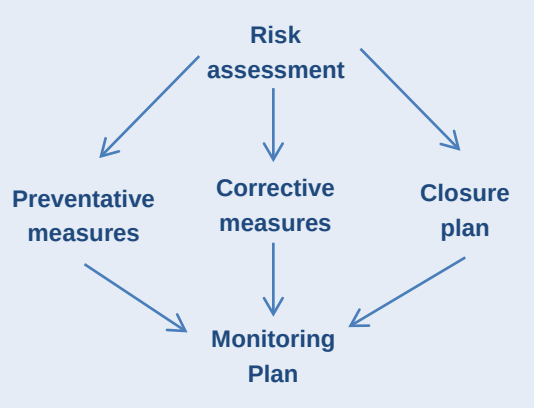
8.2.1	Injection rates	
8.2.2	Injection and formation pressures	
8.2.3	Mechanical integrity	
8.2.4	Properties and composition of the CO_2 stream	
8.3	The impact hypothesis forms a basis for the monitoring plan	n/a

Furthermore, a number of monitoring strategies are highlighted for consideration:

Para	Specific Guideline requirements	Evaluation
8.7.1	Performance monitoring, to correlate how well the CO_2 is remaining in the intended formation	
8.7.2	Detecting migration in surrounding geological layers	
8.7.3	Monitoring the seafloor and overlaying water to detect leakage into the marine environment	
8.7.4	Monitoring marine communities (benthic and water column) to detect effects of CO_2 leakage	
8.10	The results of the monitoring should be review at regular intervals	

5.8.2 Summary of information submitted

8.1 - The applicant provides an initial[22] monitoring plan which is designed to be employed to meet the objectives of the risk management plan and, where necessary, the corrective measures plan. The monitoring plan covers: pressure measurement at the well, annular pressures, volume of injected CO_2, quality of injected gas, measurements of integrity of the well and measurements of irregularities at the well. The risk assessment, corrective measures and monitoring plan are inextricably linked, and clear links are made to the role of monitoring both for site performance and assessing the effectiveness of corrective measures, if needed. The risk management framework as submitted in the application is provided in Figure 4.



[22] It is stated that the monitoring plan will be updated prior to injection

Figure 4: The 5 interlinked elements of the risk management plan as defined by the applicant

The monitoring plan follows the 'traffic light model'. Expected values are considered as green, meaning the site is behaving as expected. Unexpected values would trigger a yellow light, which is not an immediate cause for corrective measures, but would lead to additional measurements being taken. If measurements are far outside of the expected range, a red light would be triggered, which could mean a temporary halt to operations.

A monitoring execution plan is provided, which breaks down the various monitoring tools to be used under different circumstances. Monitoring tools are placed into categories of 'regular monitoring', 'corrective measures' in case of deviations, and 'special circumstances' in case the monitoring under corrective measures warrant such actions (See Table 15).

Table 15: Overview of the different categories of monitoring tools proposed and where applicable.

	Regular monitoring	Corrective measures	Special circumstances
Injection process	Amount and composition of CO_2, temperature and pressure	Composition of gas in P15-9	
Well properties	Integrity		Pressure, temperature and plug testing
Reservoir properties	Pressure, temperature	Seismic	
Surroundings		Possible traces of leakage	Seabed monitoring

Paragraph 8.2.1 - The applicant provides a number of possible mass flow equipment that will be utilised in the monitoring plan. Flow meters will be installed at the compressor onshore with another flow meter at the injection well on the platform.

Paragraph 8.2.2 - The pressure measurements will be made using equipment suitable in practice, such as downhole Distributed Temperature Sensors, downhole pressures sensors and memory gauges.

Paragraph 8.2.3 - For the mechanical integrity of the reservoir, reservoir pressure and temperature sensing will be used. During shut-in events, when injection has been temporarily stopped, the stabilized pressure and temperature readings will be taken. If suspected leakage occurs, the reservoir pressure of adjacent P15-9 formation will be monitored, and/or a surface seismic survey will be undertaken. For evaluating the mechanical integrity of the injection well prior to and during injection, a number of wireline logging tools are considered. For the post-injection check of the well plug, a pressure test and inspection, along with a downhole fluid sample will be taken.

Paragraph 8.2.4 - The injection stream composition will be measured by taking gas samples and analysis. An online system will be used to continually check the stream composition, coupled with individual gas samples for calibration.

Paragraph 8.3 – As mentioned in section 5.7, no explicit impact hypothesis is provided by the applicant, but sufficient information has been provided that could arguably suffice its definition and purpose (for example the risk matrix referred to in Figure 3). Furthermore, a monitoring plan is provided which is considered appropriate for the project. In this case, it does not seem appropriate to classify Specific Requirement 8.3 as partially sufficient, nor does it completely fulfil the requirements as no impact hypothesis is provided. Therefore the decision has been made to refrain from classifying it such that it does not impact the overall findings of the assessment.

Paragraph 8.7.1 - Downhole pressure and temperature measurements taken in P18-4A2 before and during injection form the basis for performance monitoring. 3D seismic imaging is expected to be ineffective as a performance monitoring tool for a storage site at this depth with such an effective seal.

Paragraph 8.7.2 - In the case that P/T measurements indicate a significant deviation from expected behaviour, it may be necessary to look for signs of migration pathways for gas in the shallow subsurface. In this case, time-lapse 3D or 2D monitoring could be used for contingent monitoring.

Paragraph 8.7.3 - In the case that P/T measurements indicate a significant deviation from expected behaviour, optional contingency monitoring may include checking for CO_2 in the sand around pockmarks on the seabed. Bubble detection at the seabed may also be achieve through the use of acoustic bubble detectors.

Paragraph 8.7.4 – No information is provided on monitoring marine communities to detect effects of leaking CO_2.

Paragraph 8.10 - The monitoring plan will be updated at least every 5 years in order to take into account changes in the risk of leakage, changes in the assessed risks to the environment and public health, new scientific knowledge and improvements to the best available technology. Prior to injection, a finalised monitoring plan will be submitted to the National Authority. The applicant must, by law, submit the results of the CO_2 monitoring at least once a year, including the technology used.

5.8.3 Reference in final storage permit

Article 10 of the final storage permit contain considerable legal mandates concerning the monitoring plan updates and reporting:

> *"1. Before commencing injection, the permit holder will update the monitoring plan, which will include details on the limits for the monitoring parameters, the categories to be monitored, the injection process, the wells, the reservoir, and the surrounding area. These details will also include the ranges TAQA Offshore B.V. listed in the traffic light model presented in the monitoring plan. The updated monitoring plan will be sent to the Minister of Economic Affairs at least six months before the injection of CO_2 commences and this plan must be approved by the Minister.*

2. Monitoring will be performed in accordance with the updated and approved monitoring plan referred to in Article 10(1).
3. By no later than four years and nine months after injection commences – and every five years thereafter – the monitoring plan will be updated based on changes in the assessment of the risk of leakage, changes in the assessment of environmental and public health risks, new scientific knowledge and improvements relating to the best available technology, and sent for approval to the Minister of Economic Affairs.
4. An updated monitoring plan will be submitted to the Minister of Economic Affairs for approval prior to the termination of the CO_2 injection."

Mitigation or remediation plan

5.8.4 Assessment overview

A mitigation or remediation plan should be in place to enable a rapid and effective response to leakage to the marine environment. The plan should cover possible seismicity in the area, and provide clearly defined actions in the case of leakage.

Table 16: Assessment overview for Section 8.ii – Mitigation or remediation plan

Para	Specific Guideline requirements	Evaluation
8.11a	A mitigation or remediation plan should be in place to enable a rapid and effective response to leakage to the marine environment	
8.11b	The plan should cover seismicity	

5.8.5 Summary of information submitted

Paragraph 8.11a - The applicant provides a definite plan for remediation. The remediation plan is risk-based and is designed upon the outcomes of the location specific risk assessment. The remediation plan works in tandem with the monitoring plan. The monitoring plan contains triggers for remediation actions, and the remediation actions must also be monitored in order to assess their effectiveness. Five types of remediation actions are mentioned: communication, additional monitoring, adjustment of operational parameters, technical changes to the system, and major adjustments. The remediation plan covers 5 undesirable occurrences and outlines remediation measures for each of them.

Paragraph 8.11b – The is no record of natural seismic activity in the area. There is also no significant evidence of induced seismic activity during the production phase of P18-4. It is recognised that induced seismicity is undesirable and could lead to the reactivation of faults and increased risk of CO_2 leakage. Mitigation measures are provided.

5.8.6 Reference in final storage permit

Section – Permit requirements, paragraph 14, subsection h. - k. states:

"Risk management, monitoring, closure, and corrective measures; TAQA submitted a risk management plan, a monitoring plan, and a provisional closure plan, and a plan for corrective measures along with its application. According to TNO and SodM these documents address all essential issues; there are no gaps that could later present problems with the CO_2 storage (incl. closure). However, these plans must be detailed further. TNO and SodM advise including a requirement that TAQA must update these four plans by no later than six months before commencing CO_2 injection, providing detailed supplemental information regarding the interrelated technological, procedural, and organisational issues linking these plans. The plans that have been submitted can be approved at this stage…"

5.9 Permit and permit conditions

5.9.1 Assessment overview

Based on the information provided by the applicant, a decision to issue a permit should only be made if all impact evaluations are completed and the monitoring requirements are determined. Section 9 specifies the data and information that any permit for CO_2 sequestration in sub-seabed formation should include.

Many of these requirements have been elaborated in the references to the final storage permit in the previous assessment sections above. Large sections of the final storage permit will not be repeated here, but instead references to the relevant sections of the permit are provided in Table 17 below.

Table 17: Assessment overview for Section 9 – Permit and permit conditions

Para	Specific Guideline requirements	Evaluation	Primary reference(s)
9.1.1	Purpose of the permit		Article 1
9.1.2	Types, amounts and source of material, including incidental substances		Article 15, Article 17, Section – Permit requirements, subsection m.
9.1.3	Location of injection facility and storage location		Article 2
9.1.4	Method of CO_2 transport		Section - National Government Coordination Regulation, paragraph 12.
9.1.5	A risk management plan		Article 11, Article 14.

9.2	Opportunities are provided for public review and participation		A legally required six week period is provided for comments on the EIA. There are no legal requirements for public participation.
9.4	Permits should be reviewed at regular intervals		Article 10, paragraph 3. Article 12 (Monitoring plan only)

6 Discussion

This part of the report provides a discussion of the results of the assessment per Section of the Specific Guidelines, including a justification of why certain information requirements or actions by the applicant and National Authority have been deemed as partially/fully non-compliant with the LP.

6.1 Section 3: Consideration of waste management options

Paragraph 3.2.2., that *"appropriate consideration of other disposal and/or sequestration options, e.g. land-based underground storage",* has been marked as partially sufficient, as there is no mention that onshore storage options have been considered in the storage application.

This omission could be justified due to the reason that onshore storage opportunities in the Netherlands are broadly located in the north eastern region of the country, over 100 km from the capture installation. In addition, in 2011 the national government issued an indefinite moratorium on the onshore storage of CO_2, due to public concerns of a planned CO_2 storage project in a gas field located partly under the town of Barendrecht, just south of Rotterdam. Therefore requirement 3.b, although not explicitly covered in the application material, should not be considered a reason for non-compliance with the LP. The National Authority experts assessing the permit would have been fully aware of the non-suitability of onshore CO_2 storage options in the Netherlands. The addition of a small amount of information to explain this would bring it in full compliance with the LP.

6.2 Section 4: Chemical and physical properties

Paragraph 4.2.3, "*an analysis should include as appropriate toxicity, persistence, potential for bio-accumulation."* has been marked as partially sufficient. However the omission of explicit information concerning this requirement can be justified by the fact that the CO_2 stream is 99.9% pure, and contains a negligible amount of incidental substances. The CO_2 itself, when stored in accordance with the risk management plan, would not have to be considered for its toxicity, persistence or potential for bio-accumulation. Therefore this should not be considered a reason for non-compliance with the LP, and a single sentence clarifying this would be sufficient.

6.3 Section 5: Action list

Paragraph 5.2, "*Development of a screening tool to assess the suitability of CO_2 streams for disposal, based on the presence of incidental substances.",* is marked as partially sufficient. The development of the screening tool is the responsibility of the National Authority, but it is unclear whether such a screening tool has been used. This needs to be checked with the National Authority.

In any case, the usefulness of a screening tool, given that only one CO_2 storage permit for one CO_2 source has applied for, could be brought into question. It would

not seem necessary or appropriate to define a screening tool to assess acceptability of different CO_2 streams at this point. Should CCS become more prevalent, with different CO_2 sources and capture systems, such a screening tool could be warranted. In the case of the ROAD project, the CO_2 stream is extremely pure, and changes to the composition including the addition of other substances other than CO_2 is well regulated in the final storage permit.

6.4 Section 6: Site selection and characterisation

Paragraph 6.2.9, refers to the inclusion of an important considerations for selecting a sub-seabed geological formation for the disposal of carbon dioxide streams, particularly *"economic and operational feasibility".* This consideration is marked as partially sufficient, as there is no explicit information provided in the application of economic or operational feasibility, although the applicant has proven its financial soundness to undertake the project, and considerable information of how the operation will be implemented has been given.

It is possible that the financial business case for the project, which would benefit from an amount of public funding, has been shared to the National Authority but, if so, this is has not been made public, and an enquiry would need to be made on this issue. As the companies involved are private operators, it is expected that approvals, investment criteria, business cases, scenarios, and the FID (final investment decision) will need to be met for the project to proceed. It is unclear to what extent the economic feasibility of the CO_2 storage project must be described in the LP application documents.

In the opinion of the author, the entire application document could be considered to be evidence of operational feasibility. Specific reference to current technical possibilities are covered in the monitoring and remedial plans. Hereby the selection of monitoring and remediation measures are partly justified based on status of technology development.

The absence of explicit reference to economic and operational feasibility is not considered an indication of non-compliance with the LP. Furthermore the relevance of this requirement for CO_2 storage activities could be queried.

6.5 Section 7: Assessment of potential effects

In Section 7, a number of information requirements have been marked as partially sufficient, but requirement attention/clarification:

Paragraph 7.6, *Evaluation of potential effects on human health, living resources, amenities and other legitimate uses of the sea.*

Paragraph 7.8.1, Magnitude to which the release increase the concentration of the substance in the seawater, sediments or biota

Paragraph 7.8.2, The degree to which the substance can produce adverse effects on the marine environment or human health.

The paragraphs listed above have a common purpose in the sense that they refer specifically to conducting an assessment of potential effects of CO_2 leakage on the marine environment. An effects assessment is also a requirement under the EU Directive of the geological storage of CO_2, upon which the provisions for CO_2 storage under the Dutch Mining Act will have been based. Paragraph 3.3.3 of Annex I of the Directive states:

"Where relevant it [the effects assessment] shall include effects of exposure to elevated CO_2 concentrations in the biosphere (including soils, marine sediments and benthic waters (asphyxiation; hypercapnia) and reduced pH in those environments as a consequence of leaking CO_2)."

In the application material submitted for the storage site, the only risk to the biosphere is restricted to possible surface elevation during the injection of CO_2. There is no assessment of CO_2 leakage to the biosphere. There were no comments from the European Commission concerning the omission of an effects assessment of CO_2 in the biosphere. It is assumed that this omission is considered acceptable as the Environmental Impact Assessment of the CO_2 storage activity results in a negligible risk of CO_2 leaking from the storage complex to the marine environment.

From the wording in the EU Directive of *"Where relevant…",* it could be interpreted that if the outcome of the risk assessment indicates negligible risk to the biosphere, and this is acceptable to the National Authority, the omission of a site specific assessment of the effects of CO_2 on parts of the marine environment such as seawater, sediments and biota is justified.

The initial paragraph of Section 7 of the CO_2 specific guidelines states:

"*For the disposal of carbon dioxide streams into the sub-seabed geological formations, the assessment should address risks posed by a leak from the carbon dioxide stream sequestration process".*

One could argue, that if the risk of leakage is considered null, such that there are no relevant risks to address, then on the grounds of economic concerns, an assessment of potential effects on the marine environment is not warranted. It is not expected that the absence of this information on an effects assessment could be a reason to determine non-compliance with the LP.

Furthermore, Section 7, paragraph 7.11 refers to the development of an *'Impact Hypothesis'*, a concise statement of the expected consequences of disposal, providing a basis for deciding whether to approve or reject the proposed disposal option and for defining environmental monitoring requirements. This paragraph has been marked as partially sufficient as there is no explicit mention of the term impact hypothesis, however sufficient information has been provided that could arguably suffice its definition and purpose.

Within the risk assessment, the applicant provides a 'risk matrix' which indicates the probability and consequences of the storage operation. From the risk matrix, a set of 'impact hypotheses' can be derived, although they are not explicitly referred to. The absence of a 'impact hypothesis' is not considered a reason to determine non-

compliance, although the National Authority could request the applicant to explicitly label the outcomes of the risk assessment using the terminology of the LP.

6.6 Section 8: Monitoring and risk management

The applicant provides a comprehensive monitoring plan, and makes a distinction between regular mandatory monitoring, and optional contingency monitoring. Although the risk of CO_2 leaking to the marine environment is considered negligible, if performance monitoring suggests possible leakage taking place, environmental monitoring on the seabed is described as part of the executable monitoring plan. This includes surveying for the presence of pock marks and taking soil samples to check for elevated levels of CO_2.

Paragraph 8.7.4 of the Specific Guidelines also highlights, *"Monitoring marine communities (benthic and water column) to detect effects of CO_2 leakage"* as a monitoring approach that may be included. This paragraph has been marked as partially sufficient, as despite the inclusion of soil sample monitoring, there is no mention of the monitoring of marine communities. It could be argued that given the inclusion of the assessment of CO_2 in the soil around pockmarks in the monitoring plan, the monitoring of marine communities in the same locations would be a justifiable inclusion as a contingency monitoring tool to satisfy the requirements of the LP. This omission is however not considered as an issue of non-compliance, as the monitoring of marine communities is described as something that 'may' be included rather than 'should' be included in a monitoring plan.

6.7 Section 9: Permit and permit conditions

Paragraph 9.2 states "*It is recommended that opportunities are provided for public review and participation in the permitting process"*. This paragraph has been marked as partially sufficient, as although the draft EIA has a legally required 6 week period for public review, there is no mention of *participation* of the public in the actual permitting process. Outside of the application process, there is evidence that the Maasvlakte CCS Project has conducted public outreach activities to the local community close to the capture site (Kombrink et al., 2011[23]) . On the other hand, it is not clear what is defined as "*participation"* under the Specific Guidelines. Evidence from literature suggest that public participation in large scale energy infrastructure projects represents a number of challenges, and most EU legal frameworks only require the minimum of consultation with the public, rather than participation (Lee et al., 2012[24]). Clarification from within the London Protocol could be sought on this matter.

Paragraph 9.4 states *"Permits should be reviewed at regular intervals"*. Notably there is only the requirement mentioned in the final storage permit to review the monitoring

[23] Kombrink, M., Jonker, T., Thonon, I. 2011. Stakeholder Management ROAD - Special Report for the Global Carbon Capture and Storage Institute. Maasvlakte CCS Project C.V., Schiedam, The Netherlands. Accessed (16.03.2016): http://decarboni.se/sites/default/files/publications/27681/final-stakeholder-management-road.pdf

[24] Lee, M., Armeni, C., de Cendra, J., Chaytor, S., Lock, S., Maslin, M., Ridgewell, C and Rydin, T. 2013. Public participation and climate change infrastructure. J Environmental Law, 25 (1): 33-62.

plan at 5 year intervals in the permit, and no mention of changes to the storage permit itself. This omission was raised by the European Commission in their Opinion on the draft storage permit. While such provisions are regulated under the Dutch Mining Act, it should also be reflected in the final storage permit. The absence of a regular review interval could be considered in non-compliance with the LP.

7 Summary of findings

With reference to Figure 5 below, that based on the assessment conducted, information has been provided by the applicant to cover at least 82% of the requirements of the Specific Guidelines for CO_2 sequestration in sub-seabed formations. Eight requirements are deemed to require attention or clarification where only partial information has been submitted, or where the requirement would appear non-applicable. Only one requirement of the Specific Guidelines is considered to be insufficiently addressed in the permit conditions. Figure 6 provides an overview of the results of the compliance assessment per Section.

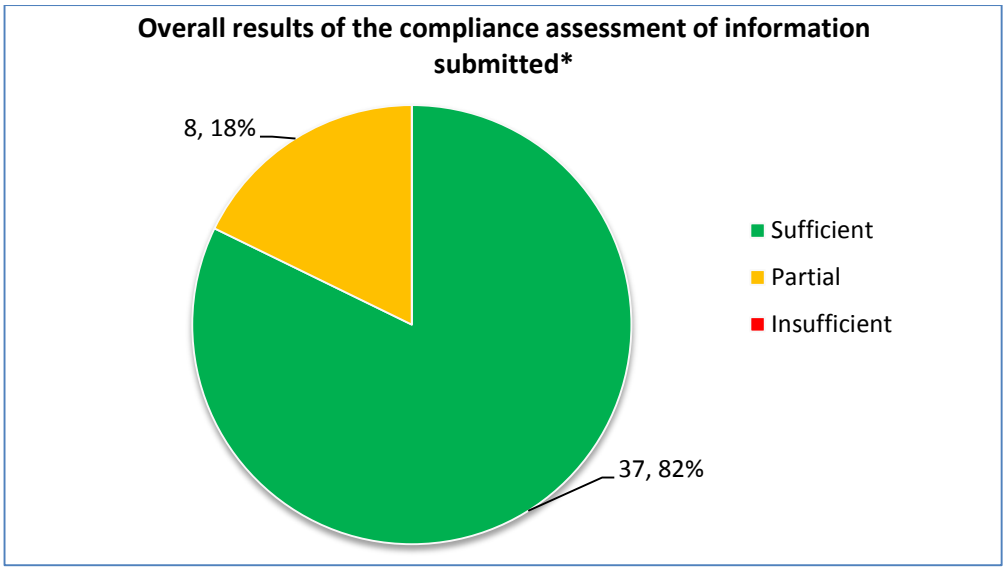


Figure 5: The overall results of the compliance assessment. * *Totals do not include the assessment of Section 5 - Action List, and Section 9 Permit and Permit Conditions, as these are the responsibility of the National Authority*

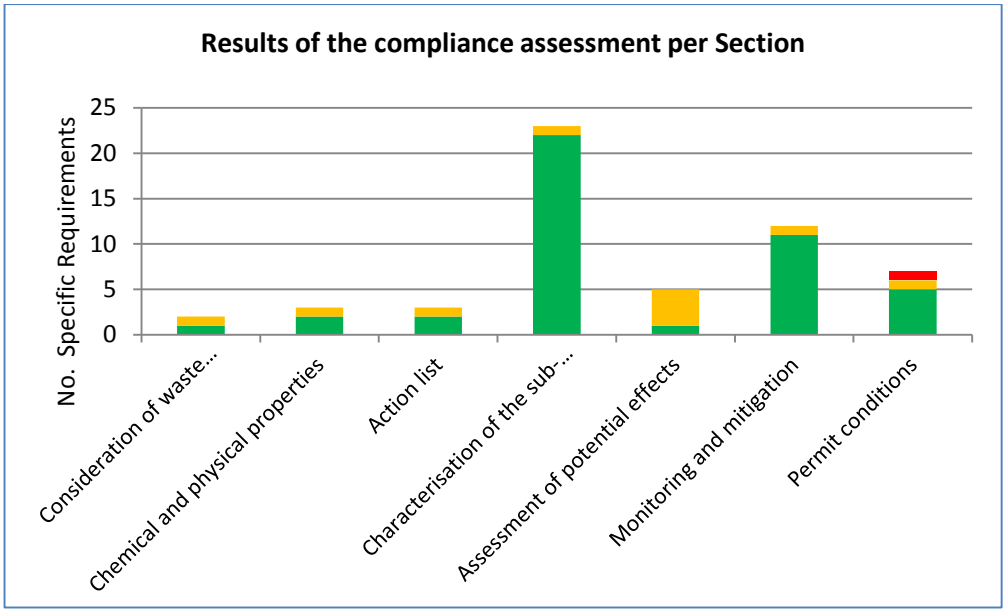


Figure 6: Results of the compliance assessment per Section

7.1 Conclusion and recommendations

It can be concluded from this assessment that in the case of the P18-4 CO_2 storage permit, the material submitted to the National Authority is broadly sufficient to allow an evaluation of the planned CO_2 storage activities in a manner consistent with the provisions of the 1996 London Protocol. Based on the information submitted by TAQA B.V., no information was sufficiently absent that would indicate clear non-compliance with the CO_2 Specific Guidelines.

There are however eight areas from within the application material whereby the information or justification is partially sufficient, but may require further clarification. In addition, there is also one area of partial compliance and one of non-compliance from within the permit conditions, which is the responsibility of the National Authority. These issues are discussed in Section 6; however, a number of recommendations are provided below.

The recommendations are relevant both for this specific case study, but also for future CO_2 storage permits in marine territories of contracting parties. The recommendations are categorised according to stakeholder group:

7.1.1 Recommendations to the National Authority

- It should be requested that within any future permit applications, that the applicant makes a statement recognising the applicability of the 1996 London Protocol and the requirements of the Specific Guidelines for Assessment of Carbon Dioxide for Disposal into Sub-seabed Geological Formations.

- Recognizing the focus of the London Protocol on protecting the marine environment, the applicant should provide a clear statement on the foreseen effects of CO_2 leakage on the marine environment, including seawater, sediments and biota. The statement should be based on the outcomes of the risk assessment. Should the outcome of the risk assessment indicate a negligible risk to the marine environment, and this is acceptable to the National Authority, no further site-specific effects assessment of CO_2 on the local marine environment would seem applicable. If pre-existing information is available on the marine communities, tidal effects, sediment conditions, etc. at the site or at a similarly indicative area, these could be considered for inclusion.

- The applicant should explicitly highlight an “Impact Hypothesis”, which could be an additional concise statement as part of the outcome of the standard risk assessment.

- For future permit allocations for CO_2 storage sites provided by the National Authorities of Contracting Parties, it is recommended that a brief summary of conformance with the requirements of the 1996 London Protocol is included in the preamble to the permit conditions. The summary should focus on the Impact Hypothesis and demonstrate that consideration has been given to the marine communities at the storage location.

- If it has been decided not to develop an Action List, due to a limited number of CO_2 streams for storage, this should be explicitly mentioned as part of the LP compliance summary recommended above.

- The National Authority should ensure that fixed intervals for permit review are explicitly mentioned in the permit conditions.

7.1.2 Recommendations to the London Protocol

- Clarification could be sought on the extent to which the applicant must comment on the economic and operational feasibility as a consideration in the selection of a sub-seabed geological formation for the disposal of CO_2 streams (para 6.2.9).

- Clarification could be sought on the extent and nature of public participation recommended in the permitting process of CO_2 storage sites, given a lack of experience and suitable legal provisions for enforcing such participation in some Contracting Parties.

Annex I: Permit for the storage of carbon dioxide in the P18-4 reservoir

Permit for the storage of carbon dioxide in the P18-4 reservoir, Ministry of Economic Affairs

Taqa Offshore B.V.

PO Box 11550

NL-2502 AN THE HAGUE

Date: 19 July 2013

Re: Permit to store carbon dioxide in the P18-4 reservoir

Course of the Proceedings:

- 1. On 30 June 2010, pursuant to the Dutch Mining Act [*Mijnbouwwet*] applicable on that date, TAQA Offshore B.V. (referred to hereinafter as "TAQA") filed an application with the Minister of Economic Affairs [*Minister van Economische Zaken*] for a permit as defined in Section 25(1) and Section 31b of the Dutch Mining Act for the permanent storage of carbon dioxide (referred to hereinafter as "CO_2") in the P18-4 storage reservoir, located in Block P18a of the Netherlands' portion of the continental shelf;
- 2. On 30 June and 2 August 2011, TAQA filed supplements to the application it had filed with the Minister of Economic Affairs, Agriculture and Innovation [*Minister van Economische Zaken, Landbouw en Innovatie*] (now known as the Minister of Economic Affairs). The permit application (referred to hereinafter as "the Application") comprises both the original permit application and the supplements thereto;
- 3. In 2007, OSPAR issued its Decision on the storage of carbon dioxide streams in geological formations (2007/2), which deals with the underground storage of CO_2. In 2009, the European Parliament and Council issued Directive 2009/31/EC regarding the capture, transport and storage of CO_2, which entered into effect on 25 June 2009;
- 4. In connection with the implementation of European Parliament and Council Directive 2009/31/EC regarding the storage of carbon dioxide in geological formations (which Directive also amended Council Directive 85/337/EEC, Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC and 2008/1/EC and European Parliament and Commission Regulation (EC) no. 1013/2006 (OJEC L 140)), as well as the OSPAR Decision 2007/2 on the storage of carbon dioxide streams in geological formations (Bulletin of Acts, Orders and Decrees 381), the Amendment to the Dutch Mining Act entered into force on 10 September 2011. This implemented the OSPAR

Decision and Directive 2009/31/EC in Dutch law. The subsequent amendment to the Dutch Mining Act affects the content of the application, the evaluation of the application, the procedure for granting a permit, and the content of the storage permit;

- 5. On 14 June 2011, given the provisions of Article 26a(1) of the Dutch Mining Act that were in effect on that date, as well as the provisions of Article 5(2) of Directive 2009/31/EC, the Minister of Economic Affairs placed an advertisement in the Government Gazette [*Staatscourant*] in order to afford other parties the opportunity to submit a competing application for a storage permit to store carbon dioxide in the P18-4 storage reservoir (Government Gazette 2011, no. 10244: ETM/EM/11064301);
- 6. No competing applications were received within the thirteen-week term defined in the then-applicable Section 26a(3) of the Dutch Mining Act;
- 7. On 23 November 2010, TNO Building and Infrastructure, Economic Affairs Advisory Group (referred to hereinafter as "TNO"), issued the opinion the Minister of Economic Affairs requested regarding TAQA's application;
- 8. On 25 November 2010, the State Supervision of Mines [*Staatstoezicht op de Mijnen*] (referred to hereinafter as "SodM") issued the opinion the Minister of Economic Affairs requested regarding TAQA's application;
- 9. On 2 August 2011, TNO and SodM issued supplemental opinions based on the supplements which TAQA submitted regarding its application on 30 June and 2 August 2011;

Opinion of the Mining Council

- 10. On 18 March 2011, pursuant to Section 105(3) of the Dutch Mining Act, the Mining Council [*Mijnraad*], issued its opinion on TAQA's application to the Minister of Economic Affairs. On 25 April 2012, the Mining Council issued a supplementary opinion (reference 12046628);

Opinion of the European Commission

- 11. Given the provisions of Section 31c(2) of the Dutch Mining Act, the Minister of Economic Affairs sent a request to the European Commission on 16 August 2011 requesting an opinion on drafting the permit. Based on the consultations that took place between the Commission and the Minister of Economic Affairs, several changes were made to the draft permit and the final draft of the permit was submitted to the European Commission on 16 December 2011. On 28 February 2012, the European Commission issued its opinion on the draft permit submitted on 16 December 2011;

National Government Coordination Regulation

- 12. The objective of the Rotterdam Opslag en Afvang Demonstratieproject (referred to hereinafter as "Project ROAD") is to capture CO_2 originating from E.ON Benelux's new electrical power plant at Maasvlakte in order to transport it and store it in depleted gas reservoirs in the North Sea.

  Project ROAD includes mining work to store CO_2 and constructing a pipeline. Pursuant to Section 141a(1), preamble and subsections (b) and (c), of the Dutch Mining Act, the national government coordination regulation [*rijkscoördinatieregeling*] provided for in Section 3.35(1), preamble and subsection

(c), of the Dutch Spatial Planning Act [*Wet ruimtelijke ordening*] (referred to hereinafter as "SPA") applies to this project.

This entails that the decrees necessary for Project ROAD must be jointly prepared, with the Minister of Economic Affairs coordinating the procedure. Pursuant to Section 3.31(3), read in conjunction with Section 3.35(4), of the SPA, therefore, the decrees must be subjected to the uniform public consultation procedure defined in Chapter 3.4 of the Dutch General Administrative Law Act [*Algemene wet bestuursrecht*], as well as the exceptional rules provided for in Section 3.31(3), read in conjunction with Section 3.35(4) of the SPA;

- 13. As a result, based on Section 141c(2) of the Mining Act, the Minister of Economic Affairs' decree of 18 October 2011 (bearing reference ETM/EM 11142766) regarding TAQA's application for a storage permit in the context of Project ROAD, is deemed to be a decree as defined in Section 3.35(1), preamble and subsection (b), of the SPA.
- 14. The Minister of Economic Affairs fostered the coordinated preparation of the decrees for Project ROAD. A draft of the storage permit, together with the incorporation plan and the other draft decrees, were then prepared as follows:
    - – on 22 December 2011, notice regarding the draft was published in the Government Gazette; the notice was also published in several free local newspapers [*huis-aan-huisbladen*] and regional daily newspapers;
    - – on 22 December 2011 the Minister of Economic Affairs sent a draft of the decree to TAQA;
    - – the draft decree was made available for examination from 23 December 2011 until 2 February 2012 at the Ministry of Economic Affairs, DCMR environmental service in Rijnmond, the Netherlands, the city hall building in Westvoorne, the Netherlands, and the borough offices for Hoek van Holland, the Netherlands;
    - – one informational evening was scheduled for 17 January 2012, which afforded attendees the opportunity to orally express their views on the issue;
- 15. On 30 January 2012, as a result of publishing the notices and making available the draft decrees relating to the national government coordination regulation for Project ROAD, the Hoek van Holland Borough Council [*Raad van de Deelgemeente Hoek van Holland*] expressed an opinion regarding the draft decision to grant the storage permit;

Change to the procedure to be followed in connection with storage permits

- 16. By letter dated 7 February 2013, TAQA requested the Minister of Economic Affairs to reconsider the aforementioned decree of 18 October 2011 and to refrain from applying the national government coordination regulation to the P18-A storage permit. In its request, TAQA stated that the lack of a finalised storage permit would result in delays in the technical aspects of the preparations for the intended storage of CO_2, preparations which were essential for completing Project ROAD. Since the applicability of the national government coordination regulation means that the decision-making regarding the P18-A storage permit will likely not be expedited, it would be better to process the P18-A storage permit application separately from the other decisions. By a decree of 25 March 2013, bearing reference DGETM-ED/13046070, the aforementioned decree of 18 October 2011, bearing reference ETM/EM 11142766, was withdrawn.

The Crisis and Recovery Act [*Crisis- en herstelwet*] continues to apply pursuant to Section 1.1, read in conjunction with Appendix I, of that Act. As a supplement to Section 31d(2) of the Mining Act and given the provisions of Section 3:10(1) of the General Administrative Law Act, Chapter 3.4 of the General Administrative Law Act applied to the preparation of this decree. This option was utilised in order to conclude the procedure instituted under the previously applicable national government coordination regulation.

Findings:

Grounds for refusal

- 1. The application contains sufficient information regarding the subjects listed in Section 31b of the Mining Act;
- 2. The method TAQA wishes to use to store the CO_2 is described in the storage permit application. Opinions on this matter have been obtained from TNO and SodM. These opinions indicated that, from a geological and mining technology perspective CO_2 can be stored safely in depleted gas fields in general and in the P18-4 storage reservoir in particular;
- 3. TAQA has extensive experience in the fields of geology and mining technology. TAQA holds a permit for extracting hydrocarbons in Block P18a and therefore possesses all of the available information, knowledge, and expertise regarding the P18-4 storage reservoir. TAQA also holds or co-holds other prospecting and extraction permits for the Dutch continental shelf and has therefore amassed extensive experience and technical expertise in exploration for and extracting oil and gas. Sister companies TAQA Onshore B.V. and TAQA Piek Gas B.V. are the operators listed on extraction permits for hydrocarbons and storage permits in the continental Netherlands. TAQA can use these companies' knowledge and experience in its extraction and storage activities. There is no reason for denying the storage permits based on TAQA's technological capabilities, as referred to in Section 27(1)(a) of the Mining Act;
- 4. Pursuant to Section 31b(n) of the Mining Act, TAQA's application contains a description of the financial security that will be provided. A related permit requirement is that the financial security must enter into legal and actual effect before the injection of CO_2 commences. This meets the requirement of demonstrating that sufficient funding is available for the performance of all obligations pursuant to the Mining Act and the storage permit. Based on Section 31h(1)(d), additional financial security will be provided if a change in circumstances prompts such action. Given the foregoing, there is no reason for denying the storage permits based on TAQA's financial capabilities, as referred to in Section 27(1)(a) of the Mining Act;
- 5. Section 27(2) of the Mining Act provides that a permit may be denied based on the applicant's financial capabilities if there is insufficient certainty that the applicant will fulfil the obligations imposed on it as defined in Sections 46, 47, and 102 of the Mining Act. Section 46 of the Mining Act regards the provision of security in the event that harm or loss is incurred as a result of ground movement on the landward side as defined in Section 54(d) of the Mining Act. This Section does not apply because the P18-4 storage reservoir is located on the seaward side as defined in Section 54(e) of the Mining Act. Section 47 of the Mining Act regards the provision of security for the removal or abandonment of mining equipment. As noted above, there is no reason to doubt TAQA's financial capability of meeting its obligations. Section 102 endows the Minister of Economic Affairs to demand security for the meeting of

payment obligations. Because the storage of CO_2 in the P18-4 storage reservoir in the context of Project ROAD is part of a demonstration project, there will be no obligation to pay the State a compulsory levy pursuant to Chapter 5 of the Mining Act, which means that this ground for refusal does not arise. Therefore, there is no ground for refusing the storage permit pursuant to Section 27(2) of the Mining Act;

- 6. TAQA holds, or co-holds, various exploration and extraction permits issued pursuant to the Mining Act. TAQA's operations demonstrate that it has worked efficiently and responsibly in connection with these permits. There is therefore no ground for refusing the storage permit due to inefficiency or irresponsibility as defined in Section 27(1)(c) of the Mining Act;
- 7. Section 27(1)(d) provides a ground for refusing a storage permit in the interests of safety. According to the opinion issued by TNO on 23 November 2010, CO_2 can be stored safely in depleted gas fields. In its opinion of 25 November 2010, SodM notes that TAQA would elaborate on the safety issue at a later date and that SodM would then assess this elaboration. In the opinion of 2 August 2011, SodM and TNO indicated that the safety risks for storing CO_2 in the P18-4 reservoir fell within acceptable parameters. One possible risk when storing CO_2 is that the CO_2 will leak via bore holes. Sections 67-77 of the Mining Act contain additional rules regarding the installation, use, maintenance, repair, and decommissioning of bore holes. Sealing the bore holes is an element of the plan for closing the location. The safety of the work associated with CO_2 storage is governed by the safety and healthcare system and safety and healthcare document (Articles 2.42e and 2.42f of the Working Conditions Decree [*Arbobesluit*]). Article 42, read in conjunction with Article 37, of the Mining Decree requires that the safety and healthcare system and safety and healthcare document must also provide for external safety. The "Provisional Closure Plan" [*"Voorlopig plan voor de afsluiting"*] regarding the cessation of the storage activities describes how the bore holes will be decommissioned. Given the information currently available and the statutory requirements, there is no reason for refusing the storage permit based on the safety grounds defined in Section 27(1)(d) of the Mining Act;
- 8. The assessment of the storage permit application did not reveal any cause for concern that the storage would affect national defence. Therefore, there is no reason for refusing the storage permit based on the national defence grounds defined in Section 27(1)(e) of the Mining Act;
- 9. The CO_2 will not be stored before the cessation of natural gas extraction from the P18-4 storage reservoir. The date to terminate extraction activities is planned by TAQA no later than 31 December 2014. This date will coincide with the date of withdrawal of the part area of the P18a extraction permit for which the storage permit has been requested. No provision has been made for using the P18-4 storage reservoir for any purpose other than storing CO_2. The storage of CO_2 will not hinder the planned management of minerals or geothermal energy in the area. Therefore, there is no reason for refusing the storage permit based on concerns relating to the planned management of mineral or geothermal energy formations as defined in Section 27(1)(f) of the Mining Act;
- 10. Section 27(1)(g) of the Mining Act provides a ground for refusal based on compliance with the Protocol agreed on 7 November 1996 in London relating to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter agreed in London on 29 December 1972. Since this Protocol and Convention do not apply to the storage of CO_2, they do not constitute a ground for refusal. The

possible contamination of the sea from a mining installation used for CO_2 storage, is addressed in the Mining Regulations [*Mijnbouwregeling*];

- 11. Pursuant to Section 27(1)(h) of the Mining Act, a storage permit can be refused if public interests require the area that is the subject of the storage permit application to be used for storing substances other than those listed in the application. No such interest in the storage of substances other than CO_2 has been shown to exist and there are no indications that the P18-4 storage reservoir will be needed for other substances in the near future. Therefore, there is no reason to refuse the permit based on this ground;
- 12. Given that no competing applications for a storage permit were submitted, the storage permit cannot be refused because a decision must be made regarding multiple applications for a permit as defined in Section 27(1)(i) of the Mining Act; therefore, this reason does not constitute a ground for refusal;
- 13. Pursuant to Section 27(3) of the Mining Act, the permit can be refused if storage under the proposed operating conditions would entail a significant risk of leakage or significant environmental or health risks or if granting the permit would result in more than one storage reservoir being located in the same hydraulic unit and that potential pressure interactions would be such that both reservoirs would be unable to simultaneously meet the safety requirements and the leakage of CO_2 above ground, or into sea water or the atmosphere, would entail environmental and health risks. The TNO and SodM opinions of 23 November 2010, 25 November 2010, and 2 August 2011 indicate that there is an extremely small risk that there would be leakage between the storage reservoir and the areas over, under, and near the reservoir or through well P18-4A2, the only well that has been drilled in the P18-4 reservoir. The possibility that CO_2 will migrate to the adjacent P15-9 reservoir cannot be entirely excluded. The chance of CO_2 migration will be mitigated by the limits to be set on the maximum pressure and maximum volume of CO_2 that can be stored. The monitoring plan, the risk management plan, and the plan for corrective measures devote attention to the possibility of CO_2 migrating to the P15-9 reservoir so that measures can be taken in a timely fashion to prevent any CO_2 that may leak into the P15-9 reservoir from leaking out of that reservoir. Given the limited chance of migration and leakage described above, and the fact that, should migration occur, both reservoirs will continue to meet safety requirements, there is no reason for refusing the permit based on Section 27(3). There is no pressure interaction between the P18-4 reservoir and other reservoirs that could create safety problems in other reservoirs.

Permit requirements

- 14. Section 31d(1)(a)-(m) of the Mining Act imposes requirements regarding the contents of permits for the permanent storage of CO_2; the findings are as follows with regard to subsections (a)-(m):
    - • subsection a, timeframe for CO_2 injection. TAQA plans to begin injecting CO_2 in 2015. While it is important that injection begin as soon as possible because the permit is exclusive in nature, it is also reasonable to take into account any delays that may arise in connection with Project ROAD. This means that injection must have started by no later than 1 January 2018. The duration of the injection is assumed to be the term stated in the application (8 years). The area for which the permit is being requested comprises the reservoir where the CO_2 will be stored; the suggested borders of this area are approved;

- • subsection b. TAQA has applied for a storage permit for the P18-4 reservoir. TNO evaluated the description of the reservoir and found it to be accurate. The storage complex is described in the application. The TNO and SodM opinion of 2 August 2011 contains these parties' own formulation of the storage complex, which accords with that in the application. The permit is phrased in terms of the formulation provided by TNO and SodM;
- • subsection c. The P18-4 reservoir is an independent reservoir. Storage in the reservoir will not transmit pressure to any area outside the storage reservoir. The reservoir does not form part of a hydraulic unit;
- • subsection d. It is essential to the storage process that adjustments for CO_2 injection are made to the P18-A mining equipment and the P18-4A2 well before the injection is made. In addition, TAQA will have to reach agreement with the companies that will capture and transport the CO_2 that the composition, temperature, and pressure will comply with TAQA's requirements;
- • subsection e. The volume of CO_2 that may be stored will be determined by the maximum permissible pressure in the reservoir. TAQA calculates the reservoir's capacity to be 8.1 Mton CO_2. TNO and SodM were consulted on this matter and approved this figure;
- • subsection f. The pressure limits of the stored CO_2; TAQA's application states that the reservoir pressure limit is 320 bar. This value is below the reservoir's initial pressure of 348.5 bar when gas extraction was commenced. TNO and SodM advised ensuring that the pressure in the P18-4 reservoir does not exceed the initial pressure, either before or after the injection period, in which respect such factors as thermal and diffusion effects and the pressure gradient inside the reservoir will have to be taken into account. This advice permits leeway to determine the exact pressure limits of the stored CO_2 later based on additional information;
- • subsection g. The maximum permissible CO_2 injection rates and pressure and the maximum permissible pressure of the stored CO_2; TAQA states a maximum supply capacity of 1.5 Mton per year; this is consistent with an injection rate of 47.56 kg CO_2/sec. The injection pressure may not exceed the initial pressure upon commencement of natural gas extraction from the P18-4 reservoir (348.5 bar). SodM and TNO are of the opinion that the data submitted provides an accurate description of the current knowledge and advises approving the data provided by TAQA;
- • subsections h-k. Risk management, monitoring, closure, and corrective measures; TAQA submitted a risk management plan, a monitoring plan, and a provisional closure plan, and a plan for corrective measures along with its application. According to TNO and SodM these documents address all essential issues; there are no gaps that could later present problems with the CO_2 storage (incl. closure). However, these plans must be detailed further. TNO and SodM advise including a requirement that TAQA must update these four plans by no later than six months before commencing CO_2 injection, providing detailed supplemental information regarding the interrelated technological, procedural, and organisational issues linking these plans. The plans that have been submitted can be approved at this stage. They make it clear that the CO_2 can be stored in a responsible manner and that the operation can be brought to a positive conclusion in which the CO_2 is safely and permanently stored. The plans can be finalised in the period prior to the

commencement of CO_2 injection. Taking into account the European Commission's desire to express an opinion on the detailed plans (see Opinion of the European Commission), the aforementioned updated plans must be submitted six months before the injection commences in order to give the Commission time to seek advice and assess the plans. For the monitoring plans, this period is longer than that provided in the Mining Decree (Art. 29f). This is the result of taking into account a period of no more than four months in connection with applying to the Commission for an opinion;

- o • subsection l, ground movement. The P18-4 reservoir does not lie within the line indicated in the Appendix to the Mining Act. Therefore, no requirements need be attached to the permit (Article 29h(3) Mining Decree);
- o • subsection m, composition of the CO_2 stream. The CO_2 that is stored will originate from MPP3 (E. ON's coal plant) in the Maasvlakte area; the composition of the CO_2 stream as stated in the application meets the requirements imposed by law. Because the possibility cannot be excluded that CO_2 from another source will be stored, the permit provides that the permit holder will be obliged to notify the Minister of Economic Affairs of any significant change in the composition of the CO_2 stream and will be obliged to demonstrate that the safety and integrity of the system and the storage process have not been compromised and do not present any significant risk to public health or the environment;

- 15. Financial security. Section 31d(1)(n) requires the permit to contain a description of the financial security or an equivalent provision. Given this:
  - o • the permit holder must provide financial security or an equivalent prior to injection. This security must be approved by the Minister of Economic Affairs,
  - o • the permit will state the amount in security that must be provided,
  - o • by providing its annual accounts for 2009 and 2010, TAQA adequately demonstrated that, at the time it filed its application, its own business, its parent company TAQA Energy B.V., and its parent group Abu Dhabi National Energy Company PJSC had sufficient funds to be able to provide financial security or its equivalent prior to injection that would satisfy the requirements of the Mining Decree, particularly those contained in Article 29j;
  - o • TAQA listed several possible forms of financial security in its application. At present, the bank guarantee and the escrow account at a bank with a right of pledge being vested on behalf of the State to the permit holder's claim upon the bank would seem to be the best option for satisfying the security requirement. Because the security must be provided prior to injection, the form of security will not be determined in this permit, but will be subject to a separate approval procedure as laid down in Article 29j(3) of the Mining Decree;
  - o • the following factors will determine the amount of the financial security (the amounts stated are based on the 2011 price index):
    - – monitoring costs for the term of the permit. This assumes that the injection and closure will take 9 years, with another 20-year period between closure and transfer. The term of 20 years is based on Section 31j(1)(c) of the Mining Act and the fact that the Netherlands has no practical experience with storing CO_2 in a depleted gas field. Monitoring costs have been calculated at EUR 10 million for the injection and closure period (in accordance with TAQA's statement) and EUR 100,000 for the subsequent 20-year period;

        - – possible extra monitoring costs should unforeseen circumstances arise. This amount has been calculated at EUR 10 million, based on the potential need for 3D time-lapse seismic surveys.
        - – taking corrective measures needed if things go other than planned with the storage. In accordance with TAQA's statement, an amount of EUR 7.5 million will be reserved for this;
        - – the closure of the P18-4A2 injection well and the removal of the P18-A platform, for which EUR 5.5 million (TAQA's statement) and EUR 7 million, respectively, will be reserved.
        - – taking measures to ensure that the wells in the P15-9 reservoir are closed in such a way that they will be safe should any CO_2 migrate from the P18-4 reservoir. These refer to costs that will have to be incurred in addition to the costs of abandoning wells in the traditional manner. An amount of EUR 10 million has been taken into account, based on the assumption that the wells in the P15-9 reservoir will be permanently abandoned in the fourth year of injection;
        - – the provision of a monetary amount as defined in Section 31j(1)(d) (or Section 31l(6)) of the Mining Act. This refers to the costs the Minister of Economic Affairs will have to incur when he assumes responsibility for the stored CO_2; this includes, in any case, monitoring costs for a period of 30 years. Currently, there are no indications that a longer monitoring period, and thus additional costs, will be necessary. An amount of EUR 2 million is being taken into account for this period, in accordance with TAQA's statement. This amount must be available on the permit termination date and a stipulation must be made that the amount will be available;
        - – the amount for CO_2 emission rights in the event that CO_2 should unexpectedly be released into the atmosphere, keeping in mind the total volume of CO_2 that is stored in one year and the volume of CO_2 that could escape uncontrolled through or near the well over a period of 3 months. This volume will be calculated based on the fact that a volume of 8.1 Mton CO_2 will be stored gradually over a period of 8 years and that the discharge rate at the end of the storage period will be 63 kg per second;
        - – a reserve of 20% for the uncertainty of the aforementioned factors;
    - • given the factors listed above, the permit holder must provide financial security in the amount of EUR 65.9 million for the first year of injection before commencing with the injection of CO_2 (based on the 2011 price index). For subsequent years, these amounts will be EUR 64.6 million, EUR 64.4 million, EUR 64.3 million, and EUR 52.1 million;
    - • the permit system requires the permit to state the amounts of security for the first five years after injection commences. The financial security will be updated five years after the permit is granted and then afterwards for each subsequent five-year period;
    - • the stated amounts are based on the price index dated 1 January 2011; these will be indexed for inflation. Given the nature of the amounts to be indexed, the indexation will be made in accordance with the producers prices indices. For the emission rights, an estimate will be made based on market data.
- 16. Payments. Because the storage permit is for a demonstration project, the decision has been taken to forego invoking the provisions of Section 98(2) of the Mining Act,

which permit a condition to be attached to the permit obliging the permit holder to make a payment to the State each year. This will not preclude the possibility that such a requirement will be attached to future CO_2 storage permits;

- 17. Operator. TAQA is the permit holder and operator in respect of the CO_2 storage. The CO_2 to be stored will be captured and transported by enterprises other than TAQA. In order to be certain that the CO_2 to be stored meets the permit requirements as well as statutory and regulatory requirements, TAQA will have to enter into agreements with the transport company and the party that will capture the CO_2 that stipulate that TAQA will determine the composition requirements that the CO_2 will have to meet, as well as the temperature and pressure at which the CO_2 will be delivered to the injection site;
- 18. Restriction of the area subject to the P18a extraction permit. In its application, TAQA, which also holds the P18a extraction permit, announced that it wished to terminate the extraction permit for Block P18a with effect from 1 January 2015 for the portion of the block for which the permanent CO_2 storage permit has been requested. Pursuant to Section 18 of the Mining Act, the Minister is authorised to restrict the area for which a permit has been granted if such restriction is requested by the permit holder. Since this restriction will not affect the activities in the rest of the area, the request to restrict the area covered by the P18a extraction permit can be granted. The amendment that will restrict the extraction permit will enter into effect on the same date the permanent CO_2 storage permit enters into effect (1 January 2015), thus satisfying the requirements of Section 26(6) of the Mining Act;

Opinion and supplementary opinion of the Mining Council

- 19. On 18 March 2011, the Mining Council issued an opinion based on the assumption that the permit process would be carried out based on the Mining Act as it read prior to the implementation of the CCS Directive. Because the draft permit is based on the current version of the Mining Act (as it has read since the implementation of the CCS Directive), the Mining Council was requested to submit a supplementary opinion. The Mining Council recommended granting TAQA the storage permit for the P18-4 reservoir without including a payment obligation in the permit. The permit will be issued in accordance with these recommendations.

Opinion of the European Commission

- 20. In its opinion dated 28 February 2012 regarding the draft storage permit, the European Commission generally agreed with the contents of the draft decree dated 16 December 2011. The Commission recommended making a reinterpretation of the faults between the P18-4 and P15-9 reservoirs to refer to provisions of the Mining Act and the Mining Decree and to impose requirements with regard to the operator's financial and technological capabilities.

Response to the European Commission's opinion

- 21. The European Commission's recommendation for TAQA to make a reinterpretation of the faults is interpreted as a recommendation for the permit holder to update the study of the permeability of the barrier between the P18-4 and P15-9 reservoirs before commencing the injection of CO_2. Such an update could be valuable

if it were to take recent production data and new information into account. The Commission's recommendations are being adopted (Article 18 of the storage permit).

- 22. The Commission's opinion to include references to mining legislation regard requirements from the Directive that relate to a) notifying the proper authority in the event of a leak or significant irregularity, b) amendment, assessment, updating, and revocation of the storage permit, and c) mandates regarding the provision of financial or equivalent security. The aforementioned requirements are laid down in a) Section 29e of the Mining Act, b) Section 31h of the Mining Act (with an update being considered an amendment), and c) Article 29j of the Mining Decree, respectively. These provisions impose direct obligations on the Minister of Economic Affairs and the operator, making it unnecessary to state them in the text of the permit.
- 23. Financial and professional capabilities are assessed at the time of the application (see findings 3, 4, and 5). The Minister of Economic Affairs may revoke the permit if such revocation is justified by a change in the permit holders professional and financial capabilities (Section 21(1)(c) of the Mining Act). There is sufficient certainty that the permit holder will possess the necessary financial and professional capabilities in the future.

Opinion of the Hoek van Holland Borough Council

- 24. The Hoek van Holland Borough Council (referred to hereinafter as the "Borough Council") expressed its opinion of the draft decree on 30 January 2010. This opinion expressed the Borough Council's view that insufficient assurance had been provided regarding the CO_2 storage and that there were uncertainties regarding the long-term environmental consequences, as well as the chemical reactions that could occur over the long term under high pressure and temperature.

Response to the Opinion of the Hoek van Holland Borough Council

- 25. The assurance (or lack thereof) regarding the CO_2 storage and the uncertainties regarding the long-term environmental impact and chemical reactions are extensively described in the application (see findings 1, 2, 7, and 13). The monitoring plan, risk management plan, plan for corrective measures, and closure plan provide extra safeguards to ensure safe injection and closure. These plans will be updated before injection commences (Articles 10-13; see also finding 15). Therefore, there is sufficient assurance regarding the safe storage of CO_2.

Changes to the draft decree

- 26. The European Commission's opinion led to changes being made to the draft decree of 16 December 2011. These changes concern a new Article 18 regarding updating the studies of the barrier between the P18-4 and P15-9 reservoirs.

Given:

Sections 18, 25-29, 31a(2), 31b-31e, 98(2), and 105 of the Mining Act:

Decrees:

ARTICLE I

Article 1

Taqa Offshore B.V. is granted a storage permit for the permanent storage of CO_2 and other substances that are directly related to the capture, transport, and storage of the CO_2 to be stored (to be collectively referred to hereinafter as "CO_2").

Article 2

The storage permit applies to the area enclosed by the border formed by connecting the following coordinate pairs: A-B, B-C, C-D, D-E, E-F, and F-A.

The geographic coordinates of these points are:

- A 03° 51' 39.600" E 52° 09' 18.000" N
- B 03° 52' 25.000" E 52° 09' 37.500" N
- C 03° 54' 10.800" E 52° 09' 00.000" N
- D 03° 56' 00.000" E 52° 07' 19.000" N
- E 03° 55' 12.000" E 52° 06' 48.000" N
- F 03° 53' 52.000" E 52° 07' 16.000" N

The locations of the aforementioned points are expressed in geographic coordinates calculated in accordance with the European Terrestrial Reference System.

The area for which the permit is granted has a surface area of 10.84 km^2.

Article 3

- 1. The storage reservoir is the reservoir from which hydrocarbons were extracted and is located in the area referred to in Article 2. The reservoir is described in the application and designated as P18-4.
- 2. The storage complex, as defined in Section 31d, preamble and subsection (1)(b), of the Mining Act, comprises:
    - • the storage reservoir defined in subsection (1),
    - • the layers situated above the P18-4 storage reservoir up to the base of the Chalk Group, comprising the Upper Germanic Triassic Group, Altena Group, Schieland Group, and Rijnland Group, and aquifer intervals Rijn/Rijswijk sandstone, Holland Greensand, and Texel Greensand,
    - • the fault lines surrounding the P18-4 storage reservoir,
    - • the nearby P15-9 reservoir,
    - • the layers situated under the P18-4 storage reservoir, comprising Rogenstein and Main Claystone.

Article 4

The storage reservoir does not form part of a hydraulic unit.

Article 5

Injection will commence no later than 1 January 2018. The injection period will last no longer than 8 years.

Article 6

CO_2 will not be injected until the mining equipment located in Block P18-A, including the P18-4A2 well, is modified such that CO_2 can be safely injected, as described in the application.

Article 7

The maximum permissible injection capacity is 47.56 kg CO_2 per second. The pressure in the well at the level of the storage reservoir may not exceed 348.5 bar during the injection of CO_2.

Article 8

The maximum volume of CO_2 that may be stored is 8.1 Mton.

Article 9

Both during and after the injection period, the pressure in the storage reservoir may never exceed the initial pressure of 348.5 bar that existed upon the commencement of gas extraction from the reservoir that will be used for storage. This determination must in any case take into account the thermal and diffusion effects and the pressure gradient within the reservoir.

Article 10

- 1. Before commencing injection, the permit holder will update the monitoring plan, which will include details on the limits for the monitoring parameters, the categories to be monitored, the injection process, the wells, the reservoir, and the surrounding area. These details will also include the ranges TAQA Offshore B.V. listed in the traffic light model presented in the monitoring plan. The updated monitoring plan will be sent to the Minister of Economic Affairs at least six months before the injection of CO_2 commences and this plan must be approved by the Minister.
- 2. Monitoring will be performed in accordance with the updated and approved monitoring plan referred to in Article 10(1).
- 3. By no later than four years and nine months after injection commences – and every five years thereafter – the monitoring plan will be updated based on changes in the assessment of the risk of leakage, changes in the assessment of environmental and public health risks, new scientific knowledge and improvements relating to the best available technology, and sent for approval to the Minister of Economic Affairs.
- 4. An updated monitoring plan will be submitted to the Minister of Economic Affairs for approval prior to the termination of the CO_2 injection.

Article 11

- 1. The permit holder will update the risk management plan prior to commencing the injection of CO_2. The updated plan will be sent to the Minister of Economic Affairs at least six months before the injection of CO_2 commences and this plan must be approved by the Minister.
- 2. Risk management will be performed in accordance with the updated and approved risk management plan referred to in Article 11(1).

Article 12

- 1. The permit holder will update the plan for corrective measures prior to commencing the injection of CO_2. The updated plan will be sent to the Minister of Economic Affairs at least six months before the injection of CO_2 commences and this plan must be approved by the Minister.
- 2. Corrective measures will be performed in accordance with the updated and approved risk management plan referred to in Article 12(1).
- 3. An updated plan for corrective measures will be submitted to the Minister of Economic Affairs for approval prior to the termination of the CO_2 injection.

Article 13

- 1. Prior to commencing the injection of CO_2, the permit holder will update the provisional closure plan and will submit it to the Minister of Economic Affairs for approval at least six months prior to the commencement of injection.
- 2. Closure will be performed in accordance with the updated and approved risk management plan referred to in Article 13(1).
- 3. The permit holder will make written agreements with the holder of the extraction permit for the area containing the P15-9 reservoir stipulating that all of the wells in the P15-9 reservoir will be CO_2-proof after these wells are closed.

Article 14

In the updated plans for risk management, corrective measures, monitoring, and closure the licensee must also describe the interdependence between the plans and the reports to the Dutch State Supervision of the Mines.

Article 15

The composition of the CO_2 and the substances referred to in Article 1 that directly relate to the capture, transport, and storage of the CO_2 to be stored will be consistent with the composition stated in Chapter 8 of the application of 30 June 2011. No other substances may be added. If, at any time, the composition of the CO_2 to be injected significantly deviates from the composition stated in the application, the permit holder must notify the Minister of Economic Affairs of that fact and demonstrate that the deviation will not affect the safety and integrity of the system and the storage process and that it will not present a significant environmental or public health risk.

Article 16

- 1. Prior to the injection of CO_2 the permit holder will provide financial security for the term of the storage permit, which financial security will be accepted by the Minister of Economic Affairs. The security will be provided in such a way that the State of the Netherlands will at all times be able to access the funds, independently and without the cooperation of the permit holder, the former permit holder, or third parties, in order to effect the performance of the obligations pursuant to the permit, including the obligation to acquire emission rights in the event of CO_2 leakage if the permit holder or former permit holder has not met these obligations on its own and regardless of

whether the permit or the permit holder still exists, is insolvent, or has been declared bankrupt.

- 2. Starting on the date of the first CO_2 injection, the amounts of security that will be provided are:
  - – in the first year after commencing injection: EUR 65.9 million, of which EUR 900,000 will be reserved for emission rights;
  - – in the second year: EUR 64.6 million, of which EUR 1.8 million will be reserved for emission rights;
  - – in the third year: EUR 64.4 million, of which EUR 2.7 million will be reserved for emission rights;
  - – in the fourth year: EUR 64.3 million, of which EUR 3.6 million will be reserved for emission rights;
  - – in the fifth year: EUR 52.1 million, of which EUR 4.4 million will be reserved for emission rights.
- 3. The amounts stated in Article 16(2), exclusive of the amounts for emission rights, are based on the price index dated 1 January 2011. These amounts will be adjusted for inflation based on the Statistics Netherlands indexation figure, producer prices index, SBI 2008, sales, C Industry Total.

Article 17

The permit holder will conclude agreements with the parties who will capture and transport the CO_2 intended for injection to the mining facility, which agreements will stipulate that the permit holder will determine the composition, temperature, and pressure of the CO_2 to be injected in order to safeguard the safety and integrity of the entire system and to be able to meet its obligations pursuant to this permit and the applicable laws and regulations.

Article 18

The permit holder will update its studies regarding the barrier between the P18-4 and P15-9 reservoirs and the possibility that the CO_2 from the P18-4 reservoir could penetrate the P15-9 reservoir. The permit holder will notify the Minister of Economic Affairs of the findings of these updated studies at least six months before CO_2 injection commences. In updating the studies, the permit holder will utilise the most recent data and information it has at that time.

ARTICLE II

Article 1 of the extraction permit for Block P18a, granted on by decree of 17 March 1992, bearing reference E/EMA/92008632, will be amended to read as follows:

Article 1

The extraction permit applies to the part of Block P18 bounded by the parallel between coordinate points 1 and 2, the meridian between coordinate pairs 2-3 and 7-1, the parallels between coordinate pairs 3-4, 4-5, and 6-7, as well as the arc having a radius of 5 nautical miles, the middle point of which is located at 52° 01' 30"N and 03° 54' 00" E.

The geographic coordinates of these points are:

- 1 03° 47' 00.000"E 52° 10' 00.000"N

- 2 04° 00' 00.000"E 52° 10' 00.000"N
- 3 04° 00' 00.000"E 52° 06' 03.143"N
- 4 03° 51' 53.000"E 52° 07' 10.000"N
- 5 03° 51' 32.620"E 52° 06' 15.485"N
- 6 03° 47' 16.385"E 52° 04' 16.801"N
- 7 03° 47' 00.000"E 52° 04' 21.072"N

The area enclosed by the border formed by connecting the following coordinate pairs A-B, B-C, C-D, D-E, E-F, and F-A is excluded from this permit.

The geographic coordinates of these points are:

- A 03° 51' 39.600"E 52° 09' 18.000"N
- B 03° 52' 25.000"E 52° 09' 37.500"N
- C 03° 54' 10.800"E 52° 09' 00.000"N
- D 03° 56' 00.000"E 52° 07' 19.000"N
- E 03° 55' 12.000"E 52° 06' 48.000"N
- F 03° 53' 52.000"E 52° 07' 16.000"N

The locations of the aforementioned points are expressed in geographic coordinates calculated in accordance with the European Terrestrial Reference System.

ARTICLE III

This decree will take effect on 1 January 2015.

This resolution will be announced by sending it to the applicant. This decree will be communicated by means of the Official Gazette [*Staatscourant*].

The Minister of Economic Affairs, H.G.J. Kamp

Interested parties can appeal this decree to the Administrative Law Division of the Council of State [*Afdeling bestuursrechtspraak van de Raad van State*], PO Box 20019, NL-2500 EA The Hague. The term for filing a notice of objection is six weeks, commencing on the day after the date on which the decree is made available for inspection. No appeal may be filed by an interested party who can reasonably be considered to have failed to avail himself of an opportunity to be heard regarding the draft of this decree.

This decree is subject to the Crisis and Recovery Act. This means that the interested party's notice of appeal must indicate the grounds for appealing the decree. No new grounds for appeal may be adduced after the expiry of the six-week term. The notice of appeal must state that the Crisis and Recovery Act is applicable.

Annex II: 2012 Specific guidelines for the assessment of carbon dioxide for disposal into sub-seabed geological formations

2012 SPECIFIC GUIDELINES FOR THE ASSESSMENT OF CARBON DIOXIDE FOR DISPOSAL INTO SUB-SEABED GEOLOGICAL FORMATIONS
Adopted 2 November 2012
(LC 34/15, annex 8)

1 INTRODUCTION

1.1 Carbon dioxide sequestration in sub-seabed geological formations is a process consisting of separation of carbon dioxide from industrial and energy-related sources, transport to an offshore geological formation, and long-term isolation from the atmosphere[1]. This process is one option in a portfolio of mitigation actions for stabilization of atmospheric greenhouse gas concentrations with the potential for significant benefits at the local, regional and global levels over both the short and long-terms. The intent of carbon dioxide sequestration in sub-seabed geological formations is to prevent release into the biosphere of substantial quantities of carbon dioxide derived from human activities. The aim is to retain the carbon dioxide streams within these geological formations permanently.

1.2 The risks associated with carbon dioxide sequestration in sub-seabed geological formations include those associated with leakage into the marine environment of the carbon dioxide and any other substances in or mobilized by the carbon dioxide stream. In general, there are different levels of concern regarding potential leakage that range from the local to the global over both the short- and long-terms. These Specific Guidelines deal with risks posed by carbon dioxide sequestration in sub-seabed geological formations over all timescales and primarily at the local and regional scale and thus focus on the potential effects on the marine environment in the proximity of the receiving formations.

1.3 For the purpose of these Guidelines, the following categories of substances are distinguished:

.1 the CO_2 stream, consisting of:

.1 CO_2;

.2 incidental associated substances derived from the source material and the capture and sequestration processes used:

.1 source- and process-derived substances; and

.2 added substances (i.e. substances added to the CO_2 stream to enable or improve the capture and sequestration processes); and

.2 substances mobilized as a result of the disposal of the CO_2 stream.

1.4 Annex 2 to the 1996 Protocol to the London Convention 1972, which contains the assessment of wastes or other matter that may be considered for dumping as a binding obligation to Contracting Parties, places emphasis on progressively reducing the need to use the sea for dumping of wastes. Furthermore, it recognizes that avoidance of pollution demands rigorous controls on the emission and dispersion of contaminating substances and the use of scientifically-based procedures for selecting appropriate options for waste

[1] Article 1.4.3 of the Protocol states that "the disposal or storage of wastes or other matter directly arising from, or related to the exploration, exploitation and associated offshore processing of seabed mineral resources is not covered by the provisions of this Protocol".

disposal. Using annex 2 as the basis, the "*Guidelines for the Assessment of Wastes or Other Matter that May be Considered for Dumping*"[2], as well as these Specific Guidelines were developed and are intended for use by national authorities responsible for regulating the dumping of wastes. Together they embody a mechanism to guide national authorities in evaluating applications for dumping of wastes in a manner consistent with the provisions of the London Convention 1972 or the 1996 Protocol thereto. When applying these Guidelines, uncertainties in relation to assessments of impacts on the marine environment will need to be considered and a precautionary approach applied in addressing these uncertainties.

1.5 The Guidelines should be applied with a view that acceptance of the disposal of carbon dioxide streams into sub-seabed geological formations does not remove the obligation under the 1996 Protocol to the London Convention 1972 to reduce the need for such disposal. This should be considered within the context of approaches to reducing greenhouse gas emissions and mitigating climate change.

1.6 The 1996 Protocol to the London Convention 1972 follows an approach under which dumping of wastes or other matter is prohibited except for those materials specifically listed in its annex 1, and in the context of that Protocol, the Generic Guidelines apply to the materials listed in that annex. When applying these Guidelines, they should not be viewed as a tool for the reconsideration of dumping of other wastes or other matter in contravention of that annex 1.

1.7 Contracting Parties should strive at all times to enforce procedures that minimize the potential for adverse consequences for the marine environment, human health and other legitimate uses of the sea, taking into account technological capabilities as well as economic, social and political concerns.

1.8 These Guidelines are specific to the assessment of carbon dioxide streams for disposal into sub-seabed geological formations. Adherence to the following represents neither a more restrictive nor a less restrictive regime than that of annex 2 to the Protocol. The relations between the elements of annex 2 and these Guidelines are as follows:

.1 Carbon Dioxide Stream Characterization (chapter 4, Chemical and Physical Properties);

.2 Waste Prevention Audit and Consideration of Waste Management Options (chapters 2 and 3);

.3 Action List (chapter 5);

.4 Identify and Characterize a Sub-seabed Geological Formation and the Surrounding Environment (chapter 6, Site Selection and Characterization);

.5 Determine Potential Impacts and Prepare Impact Hypothesis(es) (chapter 7, Assessment of Potential Effects);

.6 Issue Permit (chapter 9, Permit and Permit Conditions);

.7 Implement Project and Monitor Compliance (chapter 8, Monitoring and Risk Management);

.8 Field Monitoring and Assessment (chapter 8, Monitoring and Risk Management); and

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[2] The 19th Consultative Meeting of Contracting Parties to the London Convention 1972 adopted these Guidelines in 1997 and are referred to in this document as the "Generic Guidelines".

.9 Mitigation or Remediation Plan (chapter 8, Monitoring and Risk Management).

1.9 Further advice on a process of risk assessment and management of carbon dioxide streams proposed for sequestration into sub-seabed geological formations is provided in the "*Risk Assessment and Management Framework for CO_2 Sequestration in Sub-seabed Geological Structures*" that was adopted under the London Protocol in 2006.

1.10 In the case of transboundary sub-seabed geological formations that could be used by more than one country or where sub-seabed geological formations are located in areas where there is the potential for transboundary movement of CO_2 streams after injection[3] the Contracting Party where the injection occurs should be responsible for the implementation of these Specific Guidelines. Consent should be sought for the use of the sub-seabed geological formation from all countries with jurisdiction over this sub-seabed geological formation, without prejudice to international law including as reflected in the relevant provisions of UNCLOS. The Contracting Party where the injection occurs should cooperate with other relevant Contracting Parties, other States and other relevant entities, to ensure adequate sharing of information as needed and in accordance with international law, including by way of arrangement or agreement to ensure that these Specific Guidelines are implemented effectively.

1.11 These guidelines will apply in case of export of CO_2 streams for disposal according to article 6, paragraph 2, of the London Protocol once the amendment of 2009 (see resolution LP.3(4), adopted on 30 October 2009) has entered into force.

2 WASTE PREVENTION AUDIT

2.1 The initial stages in assessing alternatives to sequestration of CO_2 streams into sub-seabed geological formations should, as appropriate, include an evaluation of:

.1 amount and form of the CO_2 streams and their associated hazards; and

.2 the sources of CO_2 streams.

2.2 In general terms, if the required audit reveals that opportunities exist for waste prevention at source, an applicant is expected to formulate and implement a waste prevention strategy, in collaboration with relevant local and national agencies, which includes specific waste reduction targets and provision for further waste prevention audits to ensure that these targets are being met. Permit issuance or renewal decisions shall assure compliance with any resulting waste reduction and prevention requirements. *(Note: This paragraph is not directly pertinent to the disposal of carbon dioxide streams into sub-seabed geological formations. However, it is important to acknowledge the obligation under the 1996 Protocol to the London Convention 1972 to reduce the need for such disposal. This should be considered within the context of approaches to reducing greenhouse gas emissions and mitigating climate change.*)

3 CONSIDERATION OF WASTE MANAGEMENT OPTIONS

[3] Transboundary movement of CO_2 streams after injection is defined as movement of CO_2 streams across a national boundary within a transboundary sub-seabed geological formation after the CO_2 streams have been injected. The transboundary sub-seabed geological formations may extend into the jurisdiction of another state or into the high seas. Transboundary movement of CO_2 streams after injection is not export in the sense of article 6, of the London Protocol (see resolution LP.3(4), adopted on 30 October 2009, Recital 12).

3.1 Carbon dioxide sequestration in sub-seabed geological formations is a management option to be considered within the context of Contracting Parties' approaches to reducing greenhouse gas emissions and mitigating climate change.

3.2 Applications for disposal of carbon dioxide streams from carbon dioxide capture processes for sequestration into sub-seabed geological formations shall demonstrate that appropriate consideration has been given to:

.1 the incidental associated substances in the carbon dioxide stream and, if necessary, options for treatment to reduce or remove those substances; and

.2 other disposal and/or sequestration options, e.g. land-based underground storage.

3.3 Annex 2 to the 1996 Protocol identifies reuse and off-site recycling as options to be considered in this context. (*Note*: *These options are not directly pertinent to the disposal of carbon dioxide streams into sub-seabed geological formations*.)

3.4 According to paragraph 6 of annex 2 to the 1996 Protocol, a permit to dump wastes or other matter shall be refused if the permitting authority determines that appropriate opportunities exist to reuse, recycle, or treat the waste without undue risks to human health or the environment or disproportionate costs. As stated in paragraph 3.3 above, reuse and recycling are not directly pertinent to the disposal of CO_2 streams into sub-seabed geological formations. The practical availability of other means of disposal and/or sequestration should be considered in light of a comparative risk assessment involving both sequestration in sub-seabed geological formations and the alternatives.

4 CHEMICAL AND PHYSICAL PROPERTIES

4.1 Proper characterization of the carbon dioxide stream is essential. If the carbon dioxide stream is so poorly characterized that proper assessment cannot be made of the risks of potential impacts on human health and the environment, that carbon dioxide stream shall not be dumped.

4.2 Specific characterization of the carbon dioxide stream, including any incidental associated substances, shall take into account the chemical and physical characteristics and the potential for interaction among stream components. Such interactions could potentially affect the reactivity of the stream with the geological formation. This analysis should include as appropriate:

.1 origin, amount, form and composition;

.2 properties: physical and chemical; and

.3 toxicity, persistence, potential for bio-accumulation.

5 ACTION LIST

5.1 The Action List provides a screening mechanism for determining whether a material is considered acceptable for dumping. Each Contracting Party shall develop a national action list to provide a mechanism for screening candidate wastes and their constituents on the basis of their potential effects on human health and the marine environment. An action list can also be used as a trigger mechanism for further waste prevention or management considerations.

5.2 For carbon dioxide streams, this action list will provide a screening tool to assess acceptability for disposal into sub-seabed geological formations taking into consideration the presence and magnitude of incidental associated substances derived from the source material and the capture and sequestration processes used.

5.3 Incidental associated substances could have operational implications on CO_2 transport, injection and storage. If released, incidental associated substances could also have potential impacts on human health, safety and the marine environment. Therefore, acceptable concentrations of incidental associated substances should be related to their potential impacts on the integrity of the storage sites and relevant transport infrastructure and the risk they may pose to human health and the marine environment.

5.4 Carbon dioxide streams must consist overwhelmingly of carbon dioxide consistent with the purpose of reducing greenhouse gas emissions. However, CO_2 streams may contain low concentrations of incidental associated substances derived from the source material and the capture and sequestration processes used. Actual types and concentrations of incidental associated substances vary depending mainly on the basic process (e.g. gasification, combustion, natural gas clean-up), source material and the type of capture, transport and injection process[4].

5.5 It should be stressed that no wastes or other matter may be added for the purpose of disposing of those wastes or other matter.

6 SITE SELECTION AND CHARACTERIZATION

6.1 Proper selection of a sub-seabed geological formation for the disposal of carbon dioxide streams is of paramount importance[5]. According to paragraph 11 of annex 2 to the 1996 Protocol information required to select a dump-site shall include:

.1 physical, chemical and biological characteristics of the water-column and the seabed;

.2 location of amenities, values and other uses of the sea in the area under consideration;

.3 assessment of the constituent fluxes associated with dumping in relation to existing fluxes of substances in the marine environment; and

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4 Types and concentrations of incidental associated substances will vary on a case-by-case basis and over time as new technologies are developed and applied. For informational purposes, sections 3.6.1.1 and 3.4.1 of the IPCC Special Report on Carbon Dioxide Capture and Storage (2005) provide currently available information regarding some impurities in CO_2 streams arising from capture processes related to fuel combustion systems including: SO_2, NO, H_2S, H_2, CO, CH_4, N_2, Ar, O_2, HCl and heavy metals. It should be noted that these substances may be different for CO_2 streams from other sources such as refineries, steel plants, etc. Substances may be added to the CO_2 streams to enable or improve the efficiency or reliability of the capture and sequestration processes, e.g. corrosion inhibitors.

5 Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99 per cent over 100 years and is likely to exceed 99 per cent over 1,000 years. For well-selected, designed and managed geological storage sites, the vast majority of the CO_2 will gradually be immobilized by various trapping mechanisms and, in that case, could be retained for up to millions of years. Because of these mechanisms, storage could become more secure over longer time frames. (IPCC SRCCS (2005), Summary for Policymakers, paragraph 25) The expression "very likely" used in this statement indicates a probability between 90 per cent and 99 per cent, whereas the expression "likely" indicates a probability between 66 per cent and 90 per cent..

.4 economic and operational feasibility.

The requirements pertaining to the dumping of CO_2 streams differ from those applicable to the other wastes listed in annex 1 to the 1996 Protocol because CO_2 streams are restricted to sequestration in sub-seabed geological formations. Accordingly, the following specific guidance is provided in relation to the selection of sites for the disposal of carbon dioxide streams into sub-seabed geological formations.

Characterization of the sub-seabed geological formation

6.2 Information needed to select a sub-seabed geological formation includes a geological assessment based on a characterization of the site[6]. The following are important considerations in selecting a sub-seabed geological formation for the disposal of carbon dioxide streams:

.1 water depth and injection and storage depth;

.2 storage capacity, injectivity and permeability of the geological formation;

.3 long-term storage integrity of the geological formation;

.4 the surrounding geology, including the tectonic setting;

.5 potential migration and leakage pathways over time (including transboundary movement) and potential effects to the marine environment of leakage of CO_2;

.6 potential interactions of the injected carbon dioxide stream with the geological formation and the impacts on the relevant infrastructures and the surrounding geology, including potential mobilization of hazardous substances;

.7 possibilities for monitoring;

.8 mitigation and remediation possibilities; and

.9 economic and operational feasibility.

6.3 A significant amount of data will be needed to establish both the feasibility of a CO_2 injection site and also to provide evidence of the integrity of the site. Most data will be integrated into geological models that will be used to simulate and predict the performance of the site.

6.4 Capacity and injectivity of the sub-seabed geological formation are important considerations. The capacity and injectivity should be large enough compared to the total anticipated volume and injection rates in order to retain the carbon dioxide stream within the sub-seabed geological formation. The capacity of the storage site should be estimated on the basis of methodologies that are acceptable to the competent authorities.

6.5 In the case of transboundary sub-seabed geological formations that could be used by more than one country or where sub-seabed geological formations are located in areas where there is the potential for transboundary movement of CO_2 streams after injection, the Contracting Party where the injection occurs should cooperate with other relevant

[6] See further appendix 1 of the "*Risk Assessment and Management Framework for CO_2 Sequestration in Sub-seabed Geological Structures*".

Contracting Parties, other States, and other relevant entities, to ensure adequate sharing of information, as needed, and in accordance with international law.

Characterization of the marine area under consideration

6.6 Information should be given about location of amenities, values and other uses of the sea in the area under consideration, including the injection and storage site, and transport infrastructure where relevant, and the surrounding potentially affected area. This will include physical, hydrological, hydro-dynamical, chemical and biological characteristics of the water-column and the seabed.

6.7 Some of the important amenities, biological features and uses of the sea which may require consideration in determining the specific location of the site may include:

.1 coastal and marine areas of environmental, scientific, cultural or historical importance, such as marine protected areas or vulnerable ecosystems, e.g. coral reefs;

.2 fishing and mariculture areas;

.3 spawning, nursery and recruitment areas;

.4 migration routes;

.5 seasonal and critical habitats;

.6 shipping lanes;

.7 military exclusion zones; and

.8 engineering uses of the seafloor, including mining, undersea cables, desalination or energy conversion sites.

Evaluation of potential exposure

6.8 An important consideration in determining the suitability of a carbon dioxide stream for disposal at a specific site is the degree to which potential leakage from the sub-seabed geological formation may result in increased exposures of organisms to substances that may cause adverse effects. Risk characterization for injection of a carbon dioxide stream into a specific sub-seabed geological formation would typically be based on site-specific considerations of the potential exposure pathways, the probabilities of leakage and associated effects of the CO_2 stream, including substances mobilized as a result of the disposal of the CO_2 stream on the marine environment.

6.9 Potential migration or leakage pathways from sub-seabed geological formations include:

.1 the injection well, other abandoned or active the same geological formation;

.2 areas where permeable rock reaches the surface of the seabed (e.g. seabed outcrop);

.3 transmissive fractures of, or high-permeability zones within, the cap rock;

.4 the pore system in low-permeability cap rocks (e.g. if the capillary entry pressure at which carbon dioxide streams may enter the cap rock is exceeded) or degradation of the cap rock caused by reaction with acidified formation waters;

.5 areas where the cap rock is locally absent; and

.6 lateral migration along the storage formation (e.g. if a storage structure is overfilled beyond the spill point).

6.10 Simulation of the short- and long-term fate of stored carbon dioxide streams should be performed in order to identify potential migration and flux rates through potential leakage pathways and to assess the likelihood of leakage.

7 ASSESSMENT OF POTENTIAL EFFECTS

7.1 For the disposal of carbon dioxide streams into sub-seabed geological formations, the assessment should address risks posed by a leak from the carbon dioxide stream sequestration process. While the mechanisms resulting in risks from this process may differ from other wastes under the 1996 Protocol, the possible impacts can be identified and assessed within the framework of this Protocol. Further advice on a process of risk assessment and management of carbon dioxide streams proposed for sequestration in sub-seabed geological formations is provided in the "*Risk Assessment and Management Framework for CO_2 Sequestration in Sub-seabed Geological Structures*", as adopted in 2006 under the 1996 Protocol.

Evaluation of potential effects

7.2 The main effects to consider in relation to a leakage of a carbon dioxide stream are those that result from the dissolution of carbon dioxide in the overlying water and sediments. The effects of carbon dioxide released to water bodies depend upon the magnitude and rate of release, the chemical buffer capacities of the water body and sediment, and transport and dispersion processes. High carbon dioxide levels and changes in marine chemistry may have profound effects on metabolism of various marine organisms. Changes of pH in sediments and seawater due to carbon dioxide leakage could lead to effects on speciation, mobility or bio-availability of metals, nutrients and other compounds. It is also important that the effects of exposure to incidental associated substances, any substances mobilized by the carbon dioxide stream and displacement of saline water by the carbon dioxide stream, are considered in the effects assessment.

7.3 The extent of adverse effects of a substance is a function of the level of exposure of organisms (including humans). Exposure, in turn, is a function, inter alia, of the physical, chemical and biological processes that control the transport, behaviour, fate and distribution of a substance.

7.4 The presence of natural substances and the ubiquitous occurrence of contaminants mean that there will always be some pre-existing exposures of organisms to all substances contained in any waste that might be dumped. Concerns about exposures to hazardous substances thus relate to additional exposures as a consequence of dumping. This, in turn, can be translated back to the increase in concentration of substances from dumping compared with the previous concentration before injection.

7.5 In the assessment for disposal, particular attention should be given, but not necessarily limited to sensitive ecosystems or species, sensitive areas and habitats (e.g. spawning, nursery or feeding areas, coral reefs), migratory species and marketable

resources. There may also be potential impacts on other amenities or uses of the sea including: fishing, navigation, engineering uses, areas of special concern and value, and traditional uses of the sea.

7.6 The assessment should be comprehensive. The primary potential effects should be identified during the site selection process. The assessment for disposal should integrate information on characteristics of the carbon dioxide stream, conditions at the proposed sub-seabed geological formation, injection operations and proposed disposal techniques and specify the potential effects on human health, living resources, amenities and other legitimate uses of the sea. It should define the nature, temporal and spatial scales and duration of potential impacts based on reasonably conservative assumptions. It can be helpful to summarize these relationships in the form of a conceptual model as described in figure 2 of the "*Risk Assessment and Management Framework for CO_2 Sequestration in Sub-seabed Geological Structures*". When evaluating the spatial aspects of risk characterization, various factors are relevant to the potential area impacted, including injection volumes, the location of the CO_2 injection point and the geological characteristics of the storage reservoir and overlying structures (including potential monitoring activities).

Risk assessment

7.7 The risks of disposal should be described in terms of the likelihood of exposure, i.e. leakage of the carbon dioxide streams and associated effects on habitats, processes, species, communities and uses. The precise nature of the assessment will differ from project to project depending on disposal site characteristics and the surrounding environment. It should also take account of the capacity to intervene or mitigate in the event of leakage. This depends on the availability of relevant infrastructure at, or near to, the site to reduce the extent of exposure and concomitant effects. Emphasis should be placed on biological effects and habitat modification as well as physical and chemical change. The risks should be sufficiently described or quantified so that it is clear what variables should be assessed during monitoring.

7.8 When evaluating exposures and effects from incidental associated substances and substances mobilized as a result of the disposal of the CO_2 stream, the following factors should be considered:

.1 magnitude to which the release increases the concentration of the substance in seawater, sediments or biota in relation to existing conditions and associated effects; and

.2 the degree to which the substance can produce adverse effects on the marine environment or human health.

7.9 Given the time-scales associated with carbon dioxide sequestration in sub-seabed geological formations, it may be necessary to consider characterization of the risks at different stages of a project. The risks during injection and in the short-term may be different to the longer term risks depending upon site-specific considerations. Consideration of risks over time will be important in the design of monitoring programmes.

7.10 Paragraph 14 of annex 2 to the 1996 Protocol requires an analysis of each waste disposal option to be considered in the light of a comparative assessment of human health risks, environmental costs, hazards, economics and exclusion of future uses. If this assessment reveals that adequate information is not available to determine the likely effects of a proposed option, then this option should not be considered further. In addition, if the interpretation of the comparative assessment shows the sequestration option to be less preferable, a permit for this option should not be given. (*Note: This paragraph will not be*

directly pertinent to the disposal of carbon dioxide streams into sub-seabed geological formations when there are no alternative options and then justification of such activities should be considered within the context of approaches to reduce greenhouse gas emissions and mitigating climate change.)

Impact hypothesis

7.11 The risk characterization should lead to the development of an "*Impact Hypothesis*". This is a concise statement of the expected consequences of disposal. It provides the basis for deciding whether to approve or reject the proposed disposal option and for defining environmental monitoring requirements. Key elements in the development and testing of the Impact Hypothesis are:

.1 characterization of the CO_2 stream;

.2 conditions at the proposed storage site(s);

.3 preventive and/or mitigating measures (with appropriate performance standards);

.4 injection rates and techniques;

.5 potential release rates and exposure pathways;

.6 the potential impacts on amenities, sensitive areas, habitat, migratory patterns, biological communities and marketability of resources and other legitimate uses of the seas, including fishing, navigation, engineering uses, areas of special concern and value, and traditional uses of the sea; and

.7 the nature, temporal and spatial scales and duration of expected impacts.

7.12 The aim of sequestration of carbon dioxide streams is to ensure their permanent containment in sub-seabed geological formations in a manner that avoids significant adverse consequences for the marine environment, human health and other legitimate uses of the sea. Qualitative and quantitative elements could be defined to test the Impact Hypothesis such that – as a whole – these are consistent with that aim.

7.13 In the case of multiple carbon dioxide sequestration projects, Impact Hypotheses should take into account the potential cumulative effects of such operations. It is also important to consider the possible interactions with other uses of the sea, either existing or planned.

7.14 Each assessment should conclude with a statement supporting a decision to issue or refuse a permit for disposal.

7.15 Monitoring programmes will need to be designed to test the Impact Hypothesis(es).

8 MONITORING AND RISK MANAGEMENT

8.1 Monitoring is used to verify that permit conditions are met and that the assumptions made during the permit review and site selection process were correct and sufficient to protect the marine environment and human health. Monitoring also allows for effective management of sequestration sites. It is essential that such monitoring programmes have clearly defined objectives which may then be used to trigger mitigation or remediation plans.

8.2 Monitoring during the injection phase of CO_2 streams should be conducted to evaluate operational aspects of the sequestration process. Aspects that should be monitored include but are not limited to:

.1 injection rates;

.2 injection and formation pressures;

.3 mechanical integrity; and

.4 properties and composition of the CO_2 streams.

Monitoring during the injection phase may contribute to significantly reducing risks both during injection and over the long-term.

8.3 The Impact Hypotheses form a basis for defining the monitoring programme and should be designed to ascertain that changes in and around the receiving environment are within those predicted. The following questions must be answered:

.1 What testable hypotheses can be derived from the Impact Hypothesis?

.2 What measurements (type, location, frequency, performance requirements) are required to test these hypotheses, and determine the levels and consequences of any deviations from the expected outcome?

.3 How should the data be managed and interpreted?

8.4 For sequestration of carbon dioxide streams in sub-seabed geological formations, baseline information is required such that changes that arise due to sequestration of carbon dioxide streams can be monitored. Suitable specifications of existing (pre-disposal) conditions in the receiving area should already be contained in the application for a permit.

8.5 Due to the potentially large area of prospective sequestration sites, there will be a need to give serious consideration to the strategic design of monitoring programmes that use modelling and direct and indirect monitoring tools in a way that makes detection of CO_2 migration and potential leaks over a large area possible[7]. Moreover, long-term monitoring of potential migration or leakage of carbon dioxide streams from sub-seabed geological formations, including substances mobilized by these streams, should be undertaken over a time-scale which will allow effective verification of predictive models (performance-based system). As confidence grows that CO_2 is not migrating from the reservoir, the frequency of monitoring can be decreased.

8.6 Site-specific monitoring programmes can be designed to track the potential migration of CO_2 and, as appropriate, other substances at sequestration sites based on the initial risk characterization and sub-surface modelling. The choice of type of monitoring tool will be dependent on the size and other characteristics of the project (e.g. type of geological formation, type of injection scheme, etc.). Monitoring programmes should reflect the need for different technologies, measurements and time frames for monitoring at the various stages of a project. Additional monitoring may be required in the case of emergency situations such as leaks.

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[7] A risk-based and performance-based methodology for monitoring the CO_2 retention of geological storage sites is provided in the IPCC Guidelines for National Greenhouse Gas Inventories (2006). This will be used by countries for their greenhouse gas inventories, and provides advice for monitoring of sequestration sites in sub-seabed geological formations.

8.7 The monitoring programme should confirm the integrity of the sequestration site and contribute to safeguarding human health and the marine environment. Monitoring programmes should also be designed to minimize the impact of monitoring on the marine environment. The monitoring of sequestration of carbon dioxide streams may include:

.1 performance monitoring that correlates to how well the injected carbon dioxide stream is retained within the intended sub-seabed geological formation;

.2 monitoring the surrounding geological layers to detect migration of the carbon dioxide stream and the substances mobilized as a result of the disposal of the CO_2 stream, as appropriate, within and beyond the intended sub-seabed geological formation;

.3 monitoring the seafloor and overlaying water to detect leakage of the carbon dioxide stream, or substances mobilized as a result of the disposal of the CO_2 stream, into the marine environment. In this context, special attention should be given to abandoned wells and faults that intersect the sub-seabed geological formation or to any changes in the security of the cap rock during and after injection (faults, cracks, seismicity); and

.4 monitoring marine communities (benthic and water column) to detect effects of leaking carbon dioxide streams and mobilized substances on marine organisms.

8.8 The permitting authority is encouraged to take account of relevant research information in the design and modification of monitoring programmes. New and more efficient monitoring techniques and practices are likely to evolve and should be considered as monitoring programmes evolve. In any case, the (modified) monitoring programme should relate to the baseline information and the Impact Hypotheses.

8.9 Monitoring should be designed to determine whether impacts differ from those predicted over the short- and long-terms. This can be achieved through the acquisition of data that provide information on the extent of change that occurs as a result of the sequestration operation. Monitoring the seafloor and marine communities may be included, especially if it is suspected that migration of CO_2 above the formation could extend to the seafloor and in the event that the storage site is in the proximity of sensitive or endangered habitats and species. In order to determine the impacts, monitoring of the seafloor or of the marine community should take into account CO_2, the incidental associated substances, and the substances mobilized as a result of the disposal of the CO_2 stream.

8.10 The results of monitoring (or other related research) should be reviewed at regular intervals in relation to the objectives and can provide a basis to:

.1 modify the monitoring programme;

.2 implement, when necessary, the measures included in the mitigation or remediation plan;

.3 modify the operation, or close the site;

.4 update risk assessments;

.5 modify or revoke the permit; and

.6 modify the basis on which permit applications to sequester CO_2 streams in sub-seabed geological formations are assessed.

Mitigation or remediation plan

8.11 Although the aim of disposal of carbon dioxide streams into sub-seabed geological formations is to have no leakage, a mitigation or remediation plan should be in place to enable a rapid and effective response to leakage to the marine environment. Seismicity in the area, which could potentially lead to leakage, should be considered in these plans. The mitigation or remediation plan should consider the likelihood that carbon dioxide streams will migrate or leak as well as the types and magnitudes of potential effects of such migration or leakage over time. The requirements of the mitigation or remediation plan and the corresponding preventive and corrective measures are determined by national authorities on the basis of the potential impact of the migration or leakage on human health and the marine environment both in the short- and long-terms. If leakage poses a significant risk to the marine environment and cannot be controlled by any mitigation or remediation operation, injection should be ceased, or be modified, or the CO_2 may be transferred to a more suitable location depending upon site-specific factors.

9 PERMIT AND PERMIT CONDITIONS

9.1 A decision to issue a permit should only be made if all impact evaluations are completed and the monitoring requirements are determined. This includes an adequate site characterization, an assessment of the likelihood for migration and leakage and associated impacts and a suitable risk management plan. The provisions of the permit shall ensure, as far as practicable, that marine environmental disturbance and detriment are minimized and the benefits maximized. This includes reporting and documentation of the characteristics of the sequestration site and injection and closure operations after injection ceases. Any permit issued shall contain data and information specifying:

.1 purpose of the permit;

.2 the types, amounts and sources of materials in the carbon dioxide stream, including incidental associated substances, to be disposed into the sub-seabed geological formation;

.3 the location of the injection facility and sub-seabed geological formation;

.4 the method of carbon dioxide stream transport; and

.5 a risk management plan that includes:

.1 monitoring (both operational and long term) and reporting requirements;

.2 a mitigation or remediation plan as discussed under paragraph 8.11 above; and

.3 a site closure plan including a description of post-closure monitoring and mitigation or remediation options.

9.2 If disposal of carbon dioxide streams into sub-seabed geological formations is the selected option, then a permit authorizing this activity must be issued in advance. It is recommended that opportunities are provided for public review and participation in the permitting process. In granting a permit, the hypothesized impact occurring within the

boundaries of the dump-site, such as alterations to the physical, chemical and biological compartments of the local environment is accepted by the permitting authority. If the information provided is inadequate to determine whether a project would pose significant risks to human health or the marine environment, the permitting authority should request additional information before taking a decision on issuing a permit. If it becomes evident that a project would pose significant risks to human health or the marine environment, a permit should not be issued.

9.3 Regulators should strive at all times to enforce procedures that minimize the potential for adverse consequences for the marine environment, human health, and other legitimate uses of the sea, taking into account technological capabilities as well as economic, social and political concerns.

9.4 Permits should be reviewed at regular intervals, taking into account any changes to the composition of the CO_2 stream, results of monitoring, and the objectives of monitoring programmes. Review of monitoring results and updated risk assessments will indicate whether field programmes need to be continued, revised or terminated, and will contribute to informed decisions regarding the continuance, modification or revocation of permits. This provides an important feedback mechanism for the protection of human health, the marine environment, and other uses of the sea.

9.5 Because the aim of disposal of carbon dioxide streams into sub-seabed geological formations is to store CO_2 permanently, permits and other supporting documentation, including site location, monitoring results and mitigation or remediation plans should be archived and retained for long periods of time.