

MAKING large-scale
Carbon Capture and Storage
CCS in the Netherlands
WORK

An agenda for 2007-2020
POLICY,
TECHNOLOGY and
ORGANISATION

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- › CCS is a necessary step towards achieving a sustainable energy system.

1

- › CCS is an intermediate solution ‹
- › CCS is a central element in European Energy Policy ‹
- › CCS is an essential component of Dutch climate policy ‹

¹ CCS is a necessary step towards achieving a sustainable energy system.

1.1 CCS is an intermediate solution

Both industry and government currently face the challenge of dealing with the potential effects of climate change. International agreements (such as the Kyoto Protocol), European legislation (e.g. on emission trading) and national policy have forced these actors to think about possible ways of reducing greenhouse gas emissions. Given the fact that it will probably take about 100 years before renewable sources can meet global energy needs and that estimates suggest there is enough fossil fuel to meet energy demands in the meantime, carbon capture and storage (CCS) is probably a good way of ensuring that the growing global demand for energy does not lead to further increases in CO₂ emissions – at least in the short term. Figure 1 projects worldwide CO₂ emissions in a business-as-usual scenario. Emission reductions can be achieved through increased energy

efficiency, renewable energy and the implementation of CCS – at least for the period when fossil fuels are still being used to produce energy.

CCS is a solution that appears to be attractive to large CO₂ emitters. However, in Europe and the Netherlands it is not being employed on a large, commercial scale.

The aim of this report is to answer the question whether or not it will be feasible to introduce CSS into the Netherlands on a commercial scale by 2020. The report also explores the steps that need to be taken to prepare for large-scale implementation.

1.2 CCS is a central element in European Energy Policy

Within Europe the role of CCS is considered to be important. The European Commission identified CCS as a key technology in its 2005 Communication 'Winning the Battle Against Global Climate Change'.

CCS is also addressed in the Commissions' Green Paper on 'A European Strategy for Sustainable, Competitive and Secure Energy'. The Green Paper identifies CCS as an opportunity for near-zero emissions power generation and this can be particularly important for countries that use coal as a secure and abundant source of energy. It points out that for CCS technology is to be deployed, economic incentives must be in place as well as legal certainty for the private sector and guarantees for its environmental integrity.

In June 2006, Working Group 3 of the European Climate Change Programme of the European Commission on CCS recommended that during 2007, the Commission should produce a Communication outlining the major EU policy choices with regard to CCS. This should be accompanied by a proposal for an EU CCS regulatory framework. The recommendations suggest that these policy and regulatory frameworks should be in place as soon as possible - certainly by 2012.

The Commission was asked to address the following issues:

- › Permits for geological storage sites, including risk management, site selection, operation, monitoring, reporting, verification, closure and post-closure;
- › Liability for leakage from storage sites during operation and post-closure;
- › Clarification of the role of CCS under EU legislation, in particular in relation to waste and water and

proposals for appropriate amendments;

- › The recognition of CCS projects in the EU Emissions Trading Scheme;
- › The need - and potential options for - providing incentives for CCS in a transitional period;
- › The status of CCS projects under the rules and guidelines for state aid.

Workgroup 3 advised that the policy and regulatory framework for CCS in the EU should:

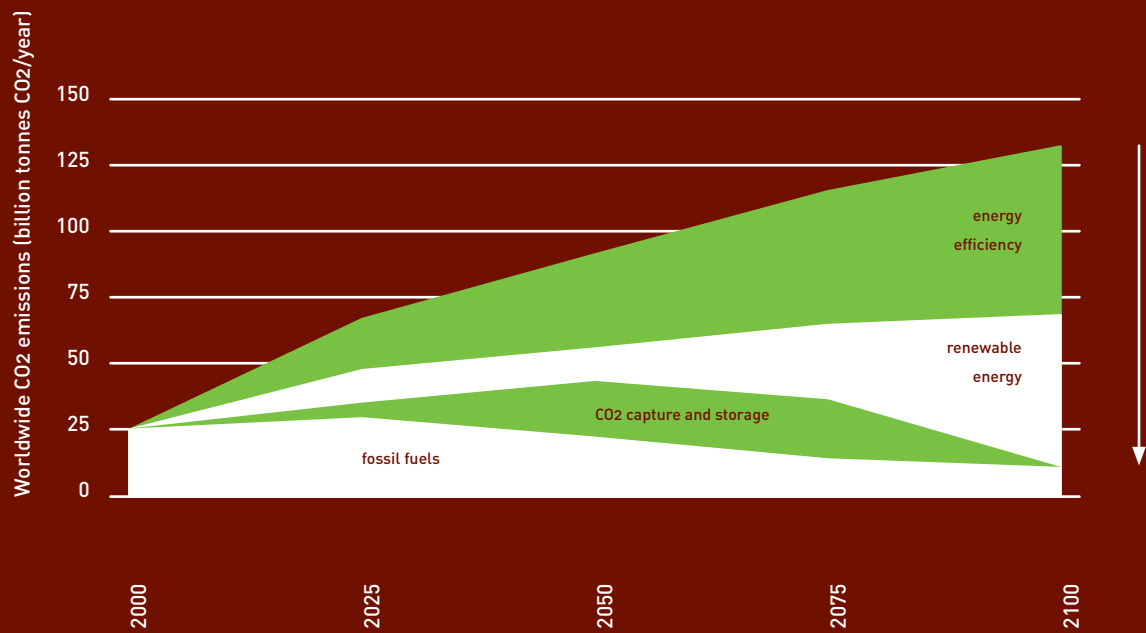
- › Ensure the appropriate management of the environmental risks associated with CCS and reduce the environmental impacts associated with the CCS chain to an acceptable level, both in the short and the long term;
- › Provide clarity, coherence and stability, enabling market operators to invest in CCS facilities across the EU under comparable regulatory conditions;
- › Provide appropriate incentives for the use of this technology. These incentives should be proportionate to the actual Green House Gas (GHG) reduction benefits delivered and not unduly disadvantage the development and deployment of other options, in particular those relating to improved energy efficiency and renewable energy;
- › Address liability issues, in particular responsibility for remediation in relation to leakage from storage sites in the short as well as the long term.

Additional recommendations included the suggestion that:

- › The Commission should provide interim guidance on the role of CCS in existing legislation, including the Emission Trading Scheme. It should also explore and clarify the role of CCS under the legislation concerning waste and water. Amendments should be proposed where particular provisions create unwarranted obstacles;

Figure 1 The potential role of CCS in a strategy for reducing CO2 emissions

Source: Ecofys, 2004



- › The Commission should further explore the potential role of existing EU instruments such as the Environmental Impact Assessment Directive, the Strategic Environmental Impact Assessment Directive, the Water Framework Directive, and the Integrated Pollution Prevention and Control Directive (IPCC).

More recently, in January 2007, the EU published a new energy and climate change strategy, in which it was suggested that the EU should take the lead by committing itself autonomously to reducing its own emissions by at least 20% by 2020. One of the key sectors where emissions could be reduced according to the Commission was the power sector. The Strategy also indicated that CCS is likely to become an important global transition technology.

At the moment, the Commission is preparing a policy and regulatory framework directive, which should be integrated into national legislation at a later stage.

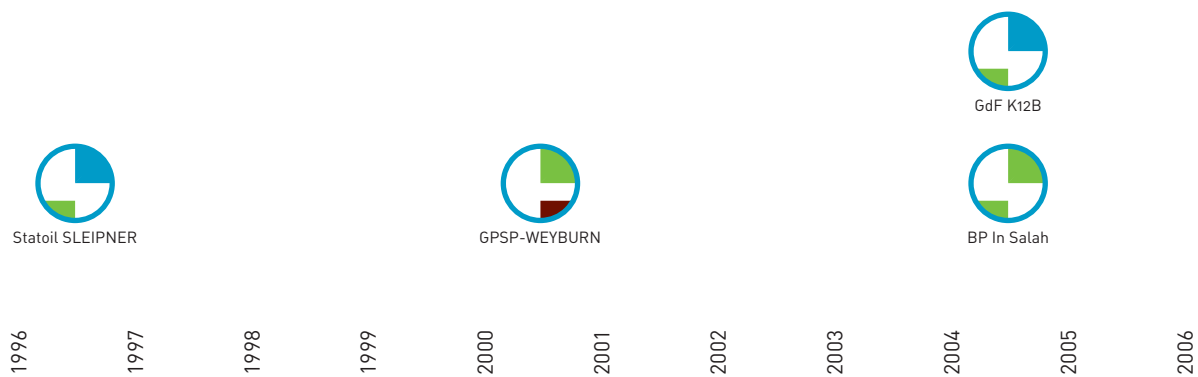
An important EU industrial initiative is the Zero Emission Fossil Fuel Power Plants Technology Platform (ZEP), which is designed to encourage EU research and development. It also has special responsibility for facilitating the demonstration of clean power plants as a first step towards their deployment. In March 2007, the ZEP platform published a strategic overview that included two plans for CCS research and deployment. According to the ZEP platform and its members, Europe needs to commit itself to a fully coordinated research agenda in order to:

- › Bring current CO₂ capture technologies (together with improved power plant efficiency) to commercial readiness by 2020;
- › Develop new concepts for implementation beyond this date.

It is possible that the EU may decide that all power plants built after 2020 should make provisions for CO₂ capture and storage. Because of a lack of experience with large-scale commercial applications of CCS, twelve large-scale CCS demonstration projects will be set up within the EU. These will be operational in 2015.

Figures 2 provides an overview of the various EU-based CCS projects. Some are already underway while others are planned. This not only confirms that CCS plays a central role in European Energy Policy, but shows – perhaps more importantly – the active role played by the corporate sector in CCS. Technology cooperation in CCS has increased and the 7th Framework Programme of the EU will stimulate this further.

Figure 2 CCS projects in Europe plotted by time of delivery
(Note the cluster around 2010. Three to five years later full-scale CCS is planned for the EU and it is possible that between 10 and 20 pilot and demonstration projects will have started before that time).
Based on N. Røkke, Sintef 2007



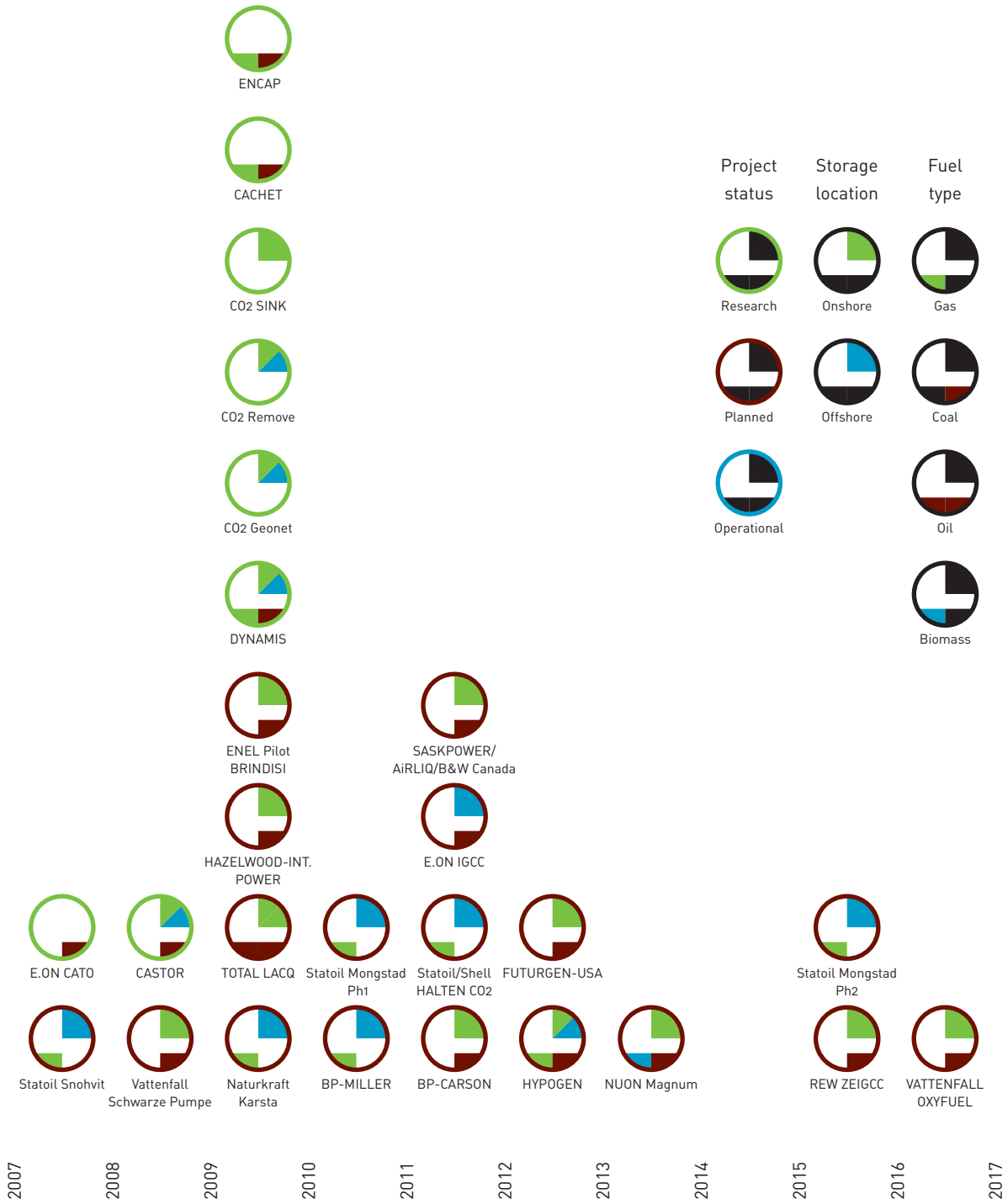


Table 1 Existing and planned coal-fired power plants in the Netherlands

Owner	Location	In operation	Capacity MWe	Type PC ¹ IGCC ²	Efficiency %	Indicative CO2 emission Mtonnes/a	Indicative CO2 capture potential Mtonnes/a
› Existing coal fired power plants							
Electrabel	Gelderland	1981	602	PC	39	3.7	3.4
NUON	Hemweg	1994	630	PC	43	3.5	3.3
E.ON	Maasvlakte	1987	520	PC	40	3.1	2.8
E.ON	Maasvlakte	1988	520	PC	40	3.1	2.8
EPZ	Borssele	1987	413	PC	40	2.5	2.2
Essent	Amer	1980	645	PC	41	3.8	3.4
Essent	Amer	1993	600	PC	43	3.4	3.0
NUON	Buggenum	1994	253	IGCC	43	1.2	1.1
› Planned new coal fired power plants							
Electrabel	Maasvlakte	2011	750	PC	46	3.9	3.5
NUON	Eemshaven	2011	720	IGCC	46	3.5	3.1
E.ON	Maasvlakte	2011	1080	PC	46	5.6	5.0
RWE	Eemshaven	2011	1600	PC	46	8.3	7.4
Essent	Geertruidenberg or Borselle	2013	1100	PC	46	5.7	5.1

Source KEMA, 2007

¹ PC | Pulverized Coal

² IGCC | Integrated Gasification Combined Cycle

1.3 CCS is an essential component of Dutch climate policy

In February 2007, the coalition agreement of the recently elected Dutch government was published. The agreement explicitly refers to CCS as one of the ways in which a more sustainable, efficient energy supply can be achieved by 2020.

This very specific reference to CCS in the Coalition Agreement confirms the fact that CCS is considered to be an essential part of Dutch climate policy. This is particularly important because the Dutch government has set itself the goal of reducing CO₂ emissions by 30% by 2020 - a target that goes beyond the goal set during the EU Summit in March 2007 when all Member States agreed to reduce their CO₂ emissions by 20% compared to the reference year 1990.

Each of the existing and newly planned coal-fired power plants, see Table 1, in the Netherlands have CO₂ capture potential and could contribute to realising the Dutch CO₂ emission objectives.

Quotation from the Dutch Coalition Agreement 2007

- › **Pijler 3: Een duurzame leefomgeving**
- › **Project: Schoner en zuiniger**
'Wij willen dat Nederland de komende kabinetsperiode grote stappen neemt in de transitie naar één van de duurzaamste en efficiëntste energievoorzieningen in Europa in 2020. Deze doelstelling voor energietransitie moet worden bereikt door energiebesparing, alternatieve energiebronnen en afvang en opslag van CO₂. In de vorm van een project Energietransitie wordt regie gevoerd met bedrijfsleven, kennisinstellingen, overheden en maatschappelijke organisaties'.

Translated from the Dutch Coalition Agreement 2007

- › **Policy foundation 3: A sustainable living environment**
- › **Project: Cleaner and more efficient**
'It is our intention in the coming Cabinet period that the Netherlands should make great strides in the transition towards developing sustainable and efficient energy facilities and infrastructures. By 2020 these should be amongst the best in Europe. This energy transition goal must be achieved through energy saving, the use of alternative sources of energy and the capture and storage of CO₂. The energy transition project will be developed and guided by the commercial sector, centres of expertise, the government and public and civil society organisations'.

- › Large-scale CCS is technically feasible by 2020 ‹

2

- › Scaling up technology and reducing costs are the main issues in CO₂ capture ‹
- › There are no technical limitations to transporting CO₂ but planning is an issue ‹
- › Sufficient storage capacity is available, but when and where is uncertain ‹

2 Large-scale CCS is technically feasible by 2020

2.1 Scaling up technology and reducing costs are the main issues in CO₂ capture

It is clear from previous studies that the overall cost of CCS is primarily determined by the cost of capture. This study investigated the expected cost of capture based on current technology as well as technology developments that might be expected in the period from 2007 to 2020.

The costs of capturing CO₂ in an Integrated Gasification Combined Cycle (IGCC) plant and a Pulverised Coal (PC) plant are shown in Figure 3. Two options have been investigated in relation to IGCC:

- › An IGCC plant which is capture ready and where a CO₂ capture installation is implemented in 2015;
- › An IGCC plant that is not capture ready but which will be retrofitted in 2015.

Three options were studied in the case of Pulverised Coal:

- › An existing plant that is retrofitted in 2015;
- › An existing capture-ready plant that is retrofitted in 2015;
- › A new plant including CO₂ capture, starting in 2020.

The costs shown in Figure 3 include investment costs, operational costs and the costs of the additional power (make up power) needed to compensate for electricity production lost as a result of capture. Within these calculations the cost of electricity production of each plant are held constant before and after implementing capture. This means that differences between the cost of electricity production for different production technologies are not reflected in the calculated costs of capture.

Figure 3 Cost of avoided CO2 for five different power plants
 Source KEMA, 2007

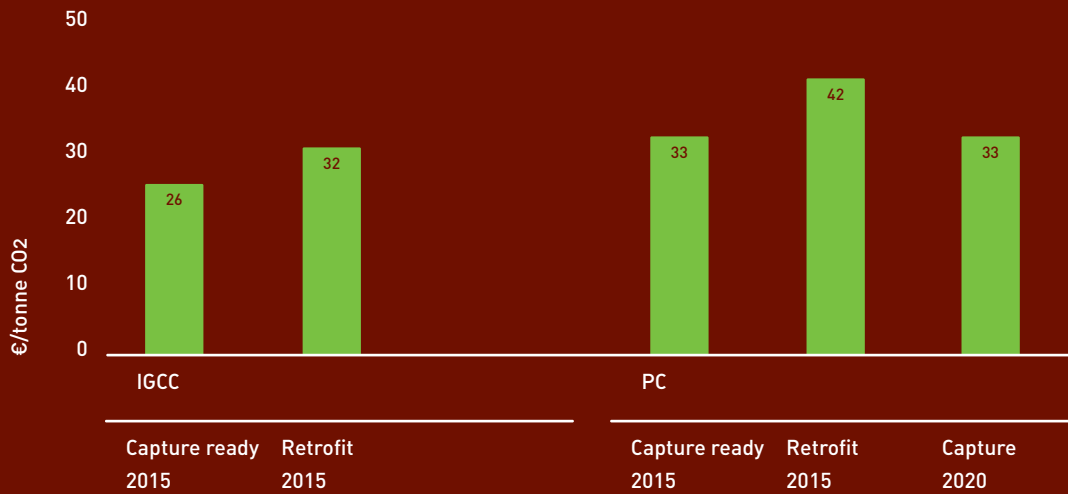


Figure 4 Projected evolution of heat requirement for solvent regeneration based on assumptions on technology development
 Source KEMA, 2007

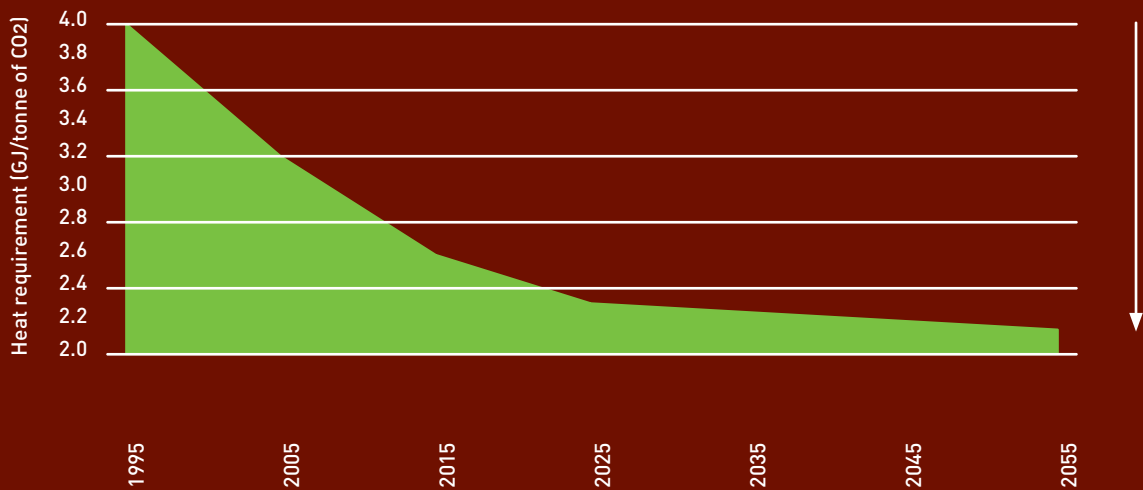


Figure 5 Comparison of efficiency penalty in IGCC and PC power plants for different CO2 capture options
 Source KEMA, 2007

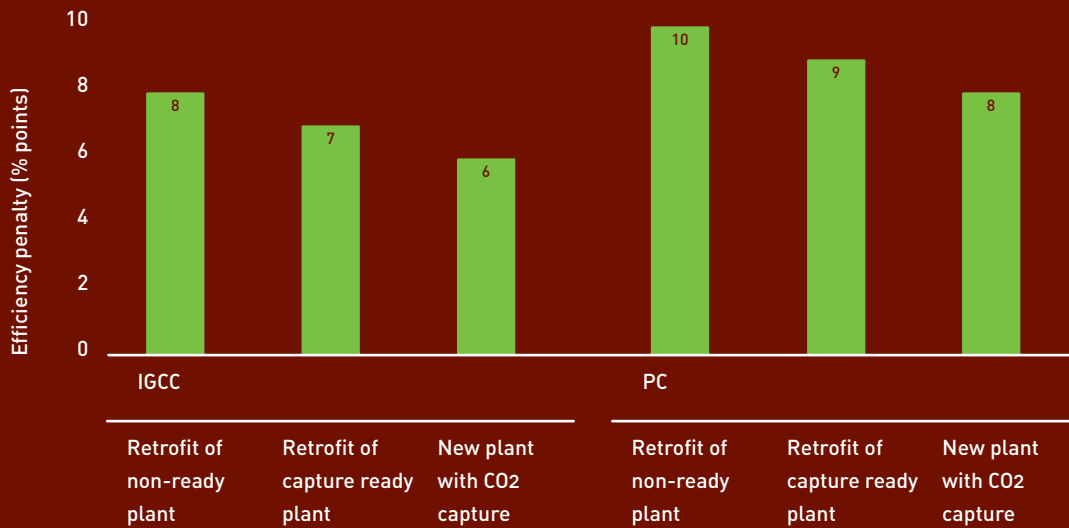
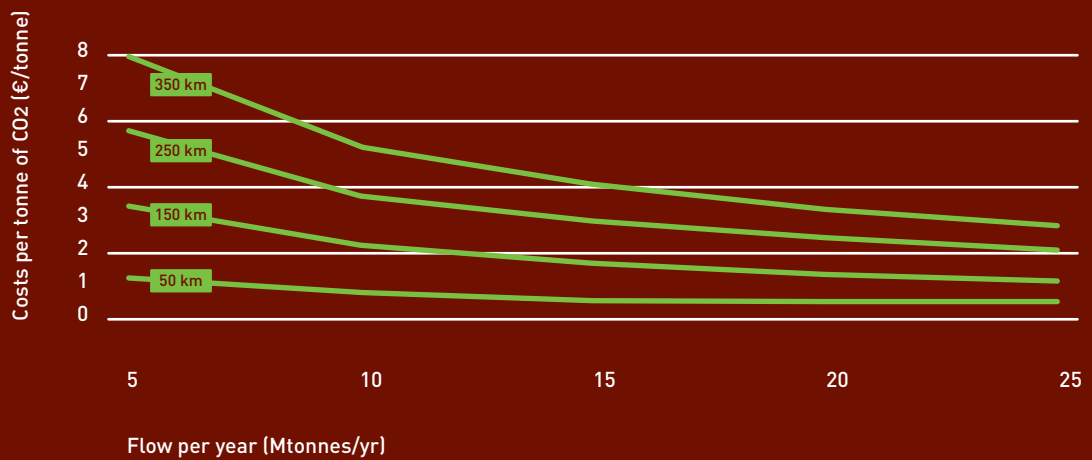


Figure 6 Costs of onshore transport over a variety of distances and capacities
 Source Ecofys, 2007



When evaluating Figure 3 it should be taken into account that there are a number of uncertainties that can influence the actual costs. Taken these uncertainties into account it can be concluded that the prices for capture are within the same price range for both technologies. The final evaluation will depend on a detailed comparison of full costs and operational experience between both technologies. In practice, it is clear that power companies that do not have IGCC experience will be inclined to avoid the risks associated with the less mature IGCC technology and instead choose the widely accepted PC technology. The data also indicates the role of further technology development. It will be less expensive to wait five years before completing implementation than to aim for early implementation in 2015.

The calculated costs of capture are still relatively high, and are strongly influenced by assumptions made in relation to anticipated developments in the solvent technology sector. The energy required for solvent regeneration is not used for electricity production and, therefore, solvent quality has a direct influence on the overall efficiency of the capture plant. As shown in Figure 4, the quality of solvents in terms of heat requirements for solvent regeneration is projected to improve substantially in the next 10-15 years. If these expectations are not realised, the costs of post-combustion capture may be 30% higher than those presented in Figure 3.

Given the fall in efficiency caused by implementing CO₂ capture, it would be better to retrofit or build new IGCC plants with CO₂ capture. PC plants are subject to slightly higher efficiency penalties, especially for retrofitted or non-capture-ready plants. The worst solution would be to retrofit existing sub-critical plants, which would incur an efficiency penalty of

around 13%-points. Taking into account positive developments in solvent technology, the efficiency reduction for capture-ready plants is expected to be between 8 and 10%-points in 2020 (see Figure 5).

Another important issue in relation to capture is the fact that post-combustion capture technology has yet to be tested in large PC plants. Before actually investing in post-combustion capture this technology must be demonstrated and tested on a realistic scale (capture of at least 30-50% of the flue gases) in order to assess the consequences of combining capture with PC plants.

Pre-combustion capture technology is relatively mature and can - to a large extent - be implemented using current knowledge and experience. It would be very useful, however, to start a demo by adding a shift reactor to an existing IGCC plant. This should be done in order to understand the consequences of pre-combustion on energy consumption and to assess the influence of higher amounts of hydrogen in the syngas on the flame stability of the burners in the gas turbine.

Table 2 provides an overview of the major obstacles to pre and post-combustion CO₂ capture.

2.2 There are no technical limitations to transporting CO₂ but planning is an issue

In general, it is technically feasible to transport high-quality CO₂. However, to improve safety and increase public confidence in the transportation process careful design and quality control is essential. It is legally possible to transport CO₂. Transport facilities are not subject to stringent legislation or safety requirements. Nevertheless, construction may take time. Permits need to be acquired and building off-shore pipelines will involve negotiations with landowners. More time is required for the design and construction of onshore pipelines (three to six years) than for offshore pipelines (approximately one to four years) because land owners are involved.

In the Netherlands, it may be possible to use existing pipelines to transport CO₂, as was the case in the OCAP project, where CO₂ of a finery is transported to greenhouses. Pressure and capacity requirements, however, may cause problems. As far as the planning of onshore pipelines is concerned, existing pipeline trajectories should be followed because this will limit planning procedure delays.

In general, the investment, operation and maintenance costs involved in the transportation of CO₂ depend on factors such as the distance between the capture location and storage site, flow size, composition, and the temperature and pressure of the stream. However, the results of a detailed techno-economic analysis of the selected onshore transportation trajectories show that - in the Netherlands - terrain conditions are 'more severe than average'. This is because the country is intersected by many waterways and freeways and is very densely populated. The investment costs of onshore trajectories are twice as high as the costs

generally associated with such trajectories. The average cost of off-shore transport will be 30% lower than the anticipated cost of onshore transport. Figure 6 provides an indication of the costs involved in the onshore transportation of CO₂.

Currently, the transportation of CO₂ by pipeline is not included in the legal frameworks governing pipeline transportation. The Ministry of the Environment has responsibility for onshore transport pipelines and offshore pipelines fall under the jurisdiction of the Ministry of Economic Affairs.

In 2008, the Ministry of the Environment will present a new 'Algemene Maatregel van Bestuur' (AMvB) which will cover the transportation of CO₂. It is suggested that this new legal framework should also include a definition of the safety requirements applicable to CO₂ pipelines as well as a clear description what can be considered acceptable technical and societal levels of contaminants in the CO₂ stream.

Long onshore pipelines require licenses from local authorities and in most cases these licences will only be granted after an Environmental Impact Assessment has been satisfactorily completed.

Table 2 Overview of major obstacles to CO2 capture

Technology	Major hurdle
Both pre and post combustion	<ul style="list-style-type: none"> › No experience with CO2 capture and compression; › Capture readiness is complex; › Increase in the Cost of Electricity (CoE); › Negative change in merit order.
Post combustion	<ul style="list-style-type: none"> › Capture plant not commercially available at desired scale; › Major efficiency and capacity reduction; › No long-term experiences with solvent, integration of capture plant in coal-fired Power Plant; › Uncertainty about solvent improvement.
Pre combustion	<ul style="list-style-type: none"> › Limited general knowledge of IGCC and limited operational experience with IGCC; › Flame stability of gas turbine after applying pre-combustion.

Source KEMA, 2007

Table 3 Storage capacity in the Netherlands

Storage type	Storage capacity Mtonnes
> Depleted gas fields	
Onshore Non-Groningen	1,600
Groningen	7,350
Offshore	1,150
	10,100
> Depleted Oil fields EOR ¹	40
> Aquifers ²	
Onshore traps	405
Offshore traps	310
	715
> Storage in deep coal fields	400
Total	11,255

Source TNO, 2007

¹ EOR | Enhanced Oil Recovery

² Aquifers | Open aquifers are not included in this table

2.3 Sufficient storage capacity is available, but when and where is uncertain

In the Netherlands, the total capacity of the different types of storage - excluding the Groningen field - is approximately 4000 million tonnes (see Table 3). Only gas fields with a capacity higher than 4 Mtonne CO₂ have been taken into account because CO₂ storage would not be economically viable in smaller fields. These figures represent maximum capacity. It is still uncertain when and how much of this capacity will actually become available. However, the capacity theoretically available is sufficient to store the CO₂ produced by power plants for a period of at least 50 years.

In general, these capacities should be taken as realistic. To a certain extent geological and engineering cut-off limits have been applied, but most of the related assumptions are not based on site-specific data. This means that there is still a significant degree of uncertainty.

Gas fields make the most important contribution to the capacity available for CO₂ storage in the Netherlands. In Table 4 this capacity has been classified as small, medium and large. The table shows that, if smaller fields are not taken into account because of high storage cost concerns and their limited practical use, overall capacity will be reduced by approximately 25%.

Around 125 gas fields are available in the Netherlands for CO₂ storage onshore and offshore. The costs and risks to develop these fields for storage will depend among other factors on storage capacity and the number of wells in a field.

It is difficult to give figures for the current number of wells in each gas field. This depends predominantly on the size and the reservoir quality of the gas field. On average one can say that in gas fields with good reservoir quality, one well is used to produce a gas volume that represents about 10 Mtonne CO₂ storage capacity. For gas fields in reservoirs with less quality, the current number of gas production wells may range up to six or eight wells per '(equivalent) 10 Mtonne storage capacity'.

Figure 7 shows the expected development of storage capacity over time. This figure was arrived at using the following assumptions:

- › The duration of a storage project is 25 years. After a field becomes available storage begins;
- › Undeveloped fields will be developed in the near future and will be available for CO₂ storage from 2025 onwards;
- › Oil fields will be used for EOR with a maximum injection flow rate of 2 Mtonne/year. This defines the storage duration;
- › Research must be carried out to clarify current uncertainties surrounding aquifer storage (storage capacities and seal capacities). It is, therefore, assumed that aquifers will not become a storage option before 2015;
- › Due to the current immature state of deep coalfield storage technology (Enhanced Coal Bed Methane (ECBM)), storage in empty coal seams will only become an option in the late 2020s.

Figure 7 actually shows the amount of CO₂ that could be stored annually if, when a storage location becomes available, it is immediately linked to a capture system and filled within a period of 25 years.

Table 4 Storage capacity in gas fields, classified in terms of small-, medium- and large- scale capacity

Storage class Mtonnes	Onshore		Offshore	
	Number of fields	Storage capacity Mtonnes	Number of fields	Storage capacity Mtonnes
> Class				
Small	4-15	36	50	425
Medium	15-50	18	23	600
Large	>50	9	2	125
Total		1,600		1,150

Source TNO, 2007

Figure 7 also shows that in 2020 there will be a total annual storage capacity of over 100 Mtonne/year. If only the large onshore gas fields are taken into account, the available capacity will still be more than 30 Mtonne/year. This figure does not include the Groningen field, which is not expected to be released before 2040.

Two factors limit the amount of storage in depleted gas fields:

- › It is expected that older wells abandoned before 1967 will be more sensitive to leakage. In theory this can be remedied but in densely populated areas this will not always be possible. An initial analysis shows that more than half of the onshore gas fields have wells that were abandoned before 1967. This means that the well integrity of these fields might be a considerable risk factor in CO₂ storage. Only a site-specific survey can determine the extent to which these older fields are actually available;
- › CO₂ storage has to compete with the other functions of a depleted gas field and in particular the way in which the field is used for underground gas storage. As long as there is no certainty about the fields that will be used for gas storage, it is impossible to specify which fields will actually become available for CO₂ storage.

CO₂ storage is feasible from a technical point of view. There are already many examples of CO₂ being pumped into underground wells and technically this does not present a problem.

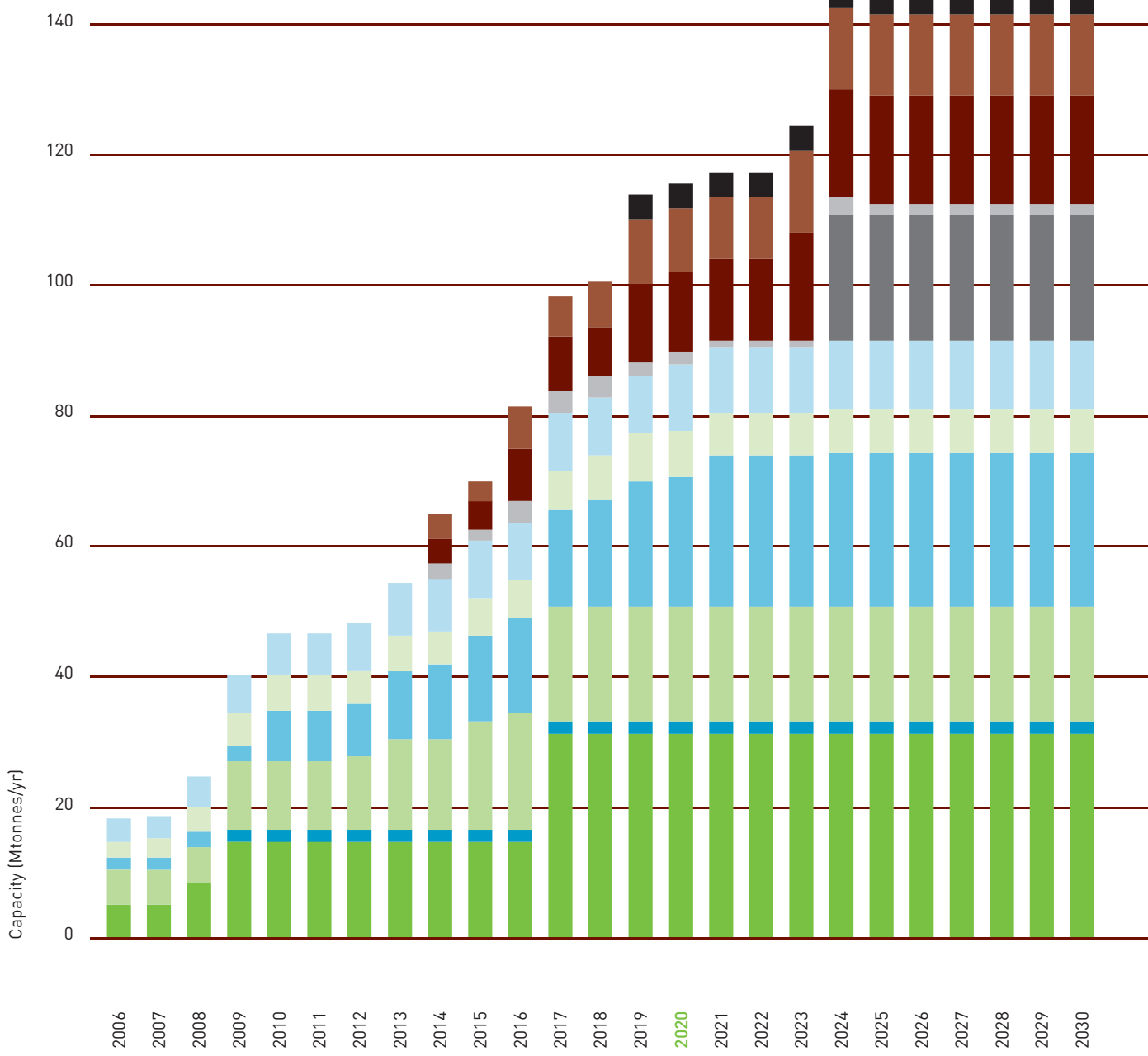
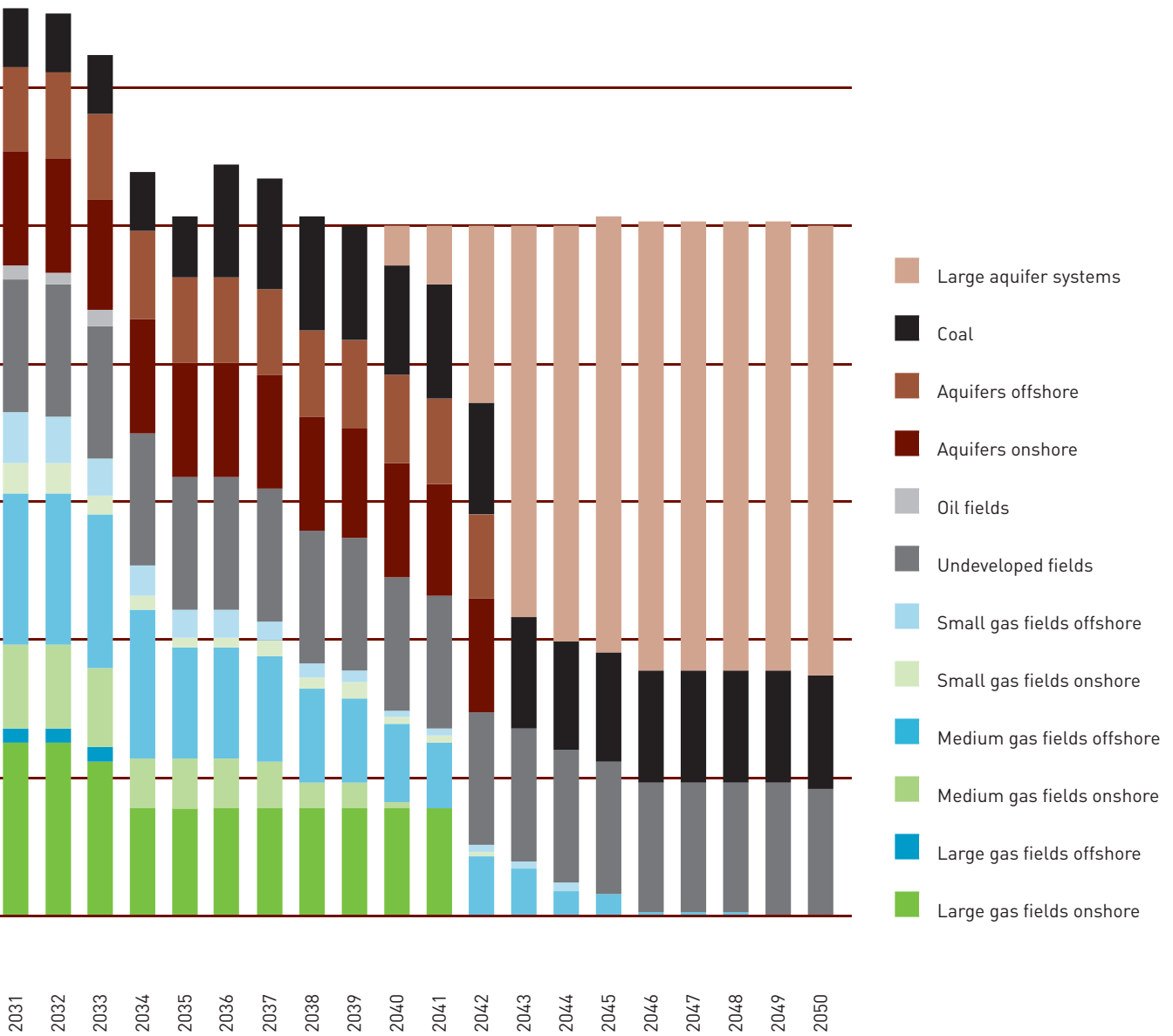


Figure 7 CO2 storage capacity per year in the Netherlands, excluding the Groningen gas field
Source TNO, 2007



- › The position stakeholders take towards CCS depends on a variety of specific circumstances.

3

- › CO2 emitters seek clear policy guidelines ‹
- › Network operators seem interested in CCS ‹
- › Gas and oil exploration and production companies have reservations about CCS ‹
- › The government is stimulating the introduction of CCS ‹

3 The position stakeholders take towards CCS depends on a variety of specific circumstances.

It is difficult to say who will be prepared to invest in Carbon Capture and Storage. A number of interviews were carried out in order to assess the position of relevant stakeholders on CCS. In addition three specific business concepts were discussed with those interviewed.

Information gathered during these interviews showed that there are significant differences in the attitudes of potential stakeholders towards CCS projects. Figure 8 provides an overview of the various stakeholders involved in future CCS projects.

Figure 8 Present and future
CCS takeholders



3.1 CO2 emitters seek clear policy guidelines

CO2 emitters - both energy producers and industry - face the uncertainty of future policy carbon constraints. However, expressions of interest in CCS indicate that these stakeholders may be prepared to take first steps towards investing in the capture technology.

One of the steps now being taken by energy producers is to include capture readiness in the plans being made for new coal-fired production plants. Making a plant capture ready is, however, only a first - and financially relatively small - step. There is greater reluctance to go further than this because of the financial implications of including Carbon Capture. The costs of Carbon Capture are high, mainly because it involves a reduction in overall electricity output.

The CO2 emitters expect the government to play a major role in reducing the current and future uncertainties of Carbon Capture investment. Table 5 shows the steps that government could take to reduce these uncertainties.

It is clear that recent climate policy decisions made by the EU and the Dutch government have removed some of these uncertainties.

When all the points referred to above have been addressed the level of uncertainty for companies will be much smaller.

3.2 Network operators seem interested in CCS

The companies in this field - including companies that produce gas pipe networks and companies that produce and deliver CO2 - see the transport of CO2 as

CO2 emitters: pre-requisites for stepping into CCS:

- › Clarification on the uncertainties identified and the commitment by government to finding
 - › potential solutions;
- Development by the government of a financial tool to ensure the profitability of CCS projects. The CO2 emitters prefer a guaranteed minimum price level for CO2 reductions based on CCS.**

According to the network companies, necessary conditions for the large-scale implementation of CCS include:

Table 5 The potential role of the government in reducing the uncertainties faced by CO2 emitters

Uncertainty	Potential solutions for government
<p>Related to the uncertainty of whether there will be a carbon constraint after 2012:</p>	<ul style="list-style-type: none"> › Declare that, if in the post-Kyoto period there is no international cap on CO2 emissions, the Dutch government will implement its own stringent CO2 policy; › Declare that within this policy there will either be a CO2 tax that makes CCS feasible or CCS will be compulsory for all new coal-fired plants.
<p>Related to the uncertainty about the future of the European emission trading system and the position of CCS in the system:</p>	<ul style="list-style-type: none"> › Press for the acceptance of CCS in the European emission trading system; › Press for an EU agreement to keep the trading system alive even if there is no post-Kyoto agreement.
<p>Related to the uncertainty about future allocations in the European emission trading system and the values of allowances:</p>	<ul style="list-style-type: none"> › Come to an agreement at the European level about the CO2 emission objectives for all the Member States for the period 2030-2040; › Come to an agreement about the allocation methodology for the next 20-30 years.

Source Personal communication, November 2006

an interesting market option. This is mainly because investing in a CO₂ network will be less expensive than investing in capture or Enhanced Oil Recovery (EOR).

In the Rijnmond area companies are looking into the possibility of constructing a CO₂ network and linking it to the OCAP pipeline that already transports CO₂ to an area of greenhouse cultivation. These companies could be the driving force behind the realisation of a CCS project.

If a CO₂ usage network were in place, these companies would be prepared to invest in the capture installations and take over part of the financial risk carried by CO₂ emitters.

- › Close cooperation amongst all those in the CCS chain (emitters, network operators, exploration companies);
- › Financial support to reduce potential investments risks in (large) transportation networks.

3.3 Gas and oil exploration and production companies have reservations about CCS

The gas exploration and production companies see the potential for carbon storage and also know that they can play a key role. At the moment, the carbon storage market does not look very interesting, because profit margins will probably be low - certainly far below the margins on gas exploration. In addition, the shortage of experienced exploration personnel encourages the gas exploration companies to adopt a cautious position in relation to actively committing their personnel to carbon storage. This will probably be a problem if CCS is implemented on a large scale.

Companies currently active on the continental shelf display a very limited interest in Enhanced Oil Recovery (EOR). However, there are signs that this interest is gradually increasing partly because - at the global level - governments are pressing companies to use EOR to enhance yields in oil fields. In addition,

The conditions necessary for implementing CCS according to the oil and gas exploration companies are:

- › Sufficient experienced personnel to manage the storage of CO₂;
- › The resolution of legal issues related to permits for storage;
- › Clear rules governing the monitoring of CO₂ storage;
- › Resolution of liability issues related to CO₂ storage.

it has been observed that larger exploration and production companies are selling their concessions to smaller companies, which are more interested in getting the maximum amount of oil out of the field even if the costs are higher. Major exploration and production companies are also involved in large-scale projects to determine the potential benefits of EOR in the North Sea area. If these projects are successful, interest in EOR can be expected to grow. EOR could be interesting for the Netherlands even though there are hardly any oil fields in the country. However, it does have large sources of CO₂ and these could be used to service EOR in the Norwegian oil fields.

3.4 The government is stimulating the introduction of CCS

The government is convinced that CCS can be an important instrument for tackling increasing CO₂ emissions. However, there is some government reluctance because CCS actually costs energy whereas all other emission reduction options save energy. The government is involved in CCS research in a variety of ways and is also developing first financial instruments (subsidies) to enable small pilots on CCS to take place in the Netherlands. The government is willing to look into the possibilities of stimulating large-scale CCS.

Other relevant stakeholders, including environmental organisations, are sceptical about CCS. This is partly a result of the discussion on climate strategy in general, and also due to a commitment to give priority to investing in energy efficiency and renewable energy. Currently only investment in CCS research seems to be acceptable. There is also considerable discussion about the uncertainty surrounding the potential (environmental) impacts of CCS.

According to the government certain conditions need to be fulfilled before CCS can be implemented:

- › A pro-active role on the part of all stakeholders towards achieving large-scale CCS;
- › Commitment from the CO₂ emitters to invest in capture technology;
- › Commitment from the CO₂ emitters to adapt CO₂ capture readiness guidelines;
- › Willingness of stakeholders to work on CCS together with the government.

- Expected costs of CCS fall within the range of expected CO₂ prices.

4

- › Financially retrofitting existing power plants is not an option ‹
- › Three basic business concepts ‹
- › The price range for CCS is between €30 and €40 per tonne of CO₂ ‹
- › EOR could help finance the development of a CO₂ network in the North Sea ‹
- › Expected prices within EU-ETS are between €20 and €50 per ton ‹

4 Expected costs of CCS fall within the range of expected CO₂ prices.

4.1 Financially retrofitting existing power plants is not an option

The efficiency of existing PC power plants after a CO₂ capture retrofit will be in the range of 22 to 32% (too low to be acceptable). Moreover, environmental regulations will not make CO₂ capture compulsory for at least a decade. The 'youngest' Dutch power plant was constructed before 1995. Taking an optimistic view this would mean that existing power plants have an operating potential of five to ten years, given an overall 25-year lifetime. As a result, the cost of electricity will increase significantly because of the short payback period. Retrofitting one of the best existing power plants would result in CO₂ capture costs of at least €40 per tonne of CO₂ avoided. Financially the efficiency loss in retrofitting existing coal plants will be almost impossible to recover

on the electricity market. In addition most existing power plants will not have enough space available to implement a capture installation.

4.2 Three basic business concepts

Three business concepts have been identified from information derived from stakeholder interviews. These concepts differ both in their basic structure and in relation to the specific roles played by the stakeholders involved. Table 6 describes the three concepts and includes organisational and financial differences.

The stand-alone concept as described in Table 6 can be seen as a necessary first step to gaining experience with CCS. It is probable that several of these projects will, in fact, be started. In the long

Table 6 Overview of the three identified business concepts

Stand-alone (island) project	Network projects	CO2 usage projects
General description:		
<ul style="list-style-type: none"> › A combination of a single CO2 source linked by a short pipeline to a single storage location; › It is important that the capacity of the storage location is such that the annual emissions of the source can be stored during the lifetime of the source. 	<ul style="list-style-type: none"> › Several sources at different locations and several storage locations are linked together by transport pipelines for CO2; › It is important to have a blueprint describing the timing of production at the source and the timing of the storage capacity. 	<ul style="list-style-type: none"> › The technical structure is similar to a network project with the important difference that the CO2 that is collected is not only stored but also utilised (e.g. for enhanced oil recovery (EOR), in greenhouses or for industrial purposes).
Organisation:		
<ul style="list-style-type: none"> › The main driver is the need for emission reduction at the source; › The responsibility for CO2 capture will always be covered by the production plant operator; › Transportation will generally be simple in a project such as this because distances are short. 	<ul style="list-style-type: none"> › The main driver is emission reduction at the source; › A network company will play a dominant role and will have to make sure that optimal use is being made of the network's transportation capacity. 	<ul style="list-style-type: none"> › The use of CO2 is a new driver for the project in addition to emission reduction. The network operator moves into a more dominant role in the whole project.
Finance:		
<ul style="list-style-type: none"> › The financial basis for these projects is the value of the emission reduction at the source. Therefore, all elements of the project will need to be financed from payments by the operator of the CO2 source. 	<ul style="list-style-type: none"> › The financial basis is the value of the emission reductions at the source. The emitters will pay a network company for the transported and stored CO2; › There is a clear risk for the network company. It has to arrange transportation and storage contracts in advance of the investments in order to guarantee full utilisation of the network. 	<ul style="list-style-type: none"> › The added value of using the CO2 will depend on the exact project structure and on whether it becomes the dominant financial driver of the project.

run, however, the network concept is more efficient because within a network it is possible to fully utilise the total capacity of all the storage sites. With a stand-alone concept, the storage sites cannot always be fully utilised.

4.3 The price range for CCS is between €30 and €40 per tonne of CO₂

An actual business case was defined for the first two concepts identified in section 4.2. The aim was to determine the extent to which they could be expected to become financially feasible within the next ten to fifteen years. A description of these cases is presented below together with an analysis of their viability. Figure 9 is an illustration of two onshore business cases.

The assumptions employed in the financial analysis were derived from those used by KEMA, TNO and Ecofys during a series of in-depth studies carried out in the Netherlands. The most important of these assumptions were:

- › A discount rate 6.5%;
- › Tax and inflation is not taken into account;
- › The operating life of all installations is 25 years;
- › All preconditions (political, technical & legal) are resolved by 2015 so that investments can start in 2015.

The integral costs of capture and storage for all elements in a CCS project are calculated from the costs per tonne of CO₂ emission avoided. The prices calculated represent the value of a tonne of CO₂ that is needed to achieve a net present value of zero for all the extra costs related to the CCS project. The extra costs for CO₂ capture include:

- › Investment in the capture plant;
- › The costs of substituting power during retrofitting (make up power);

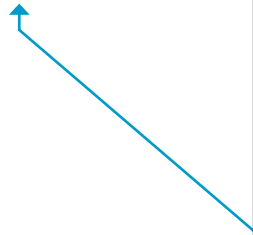
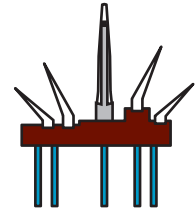
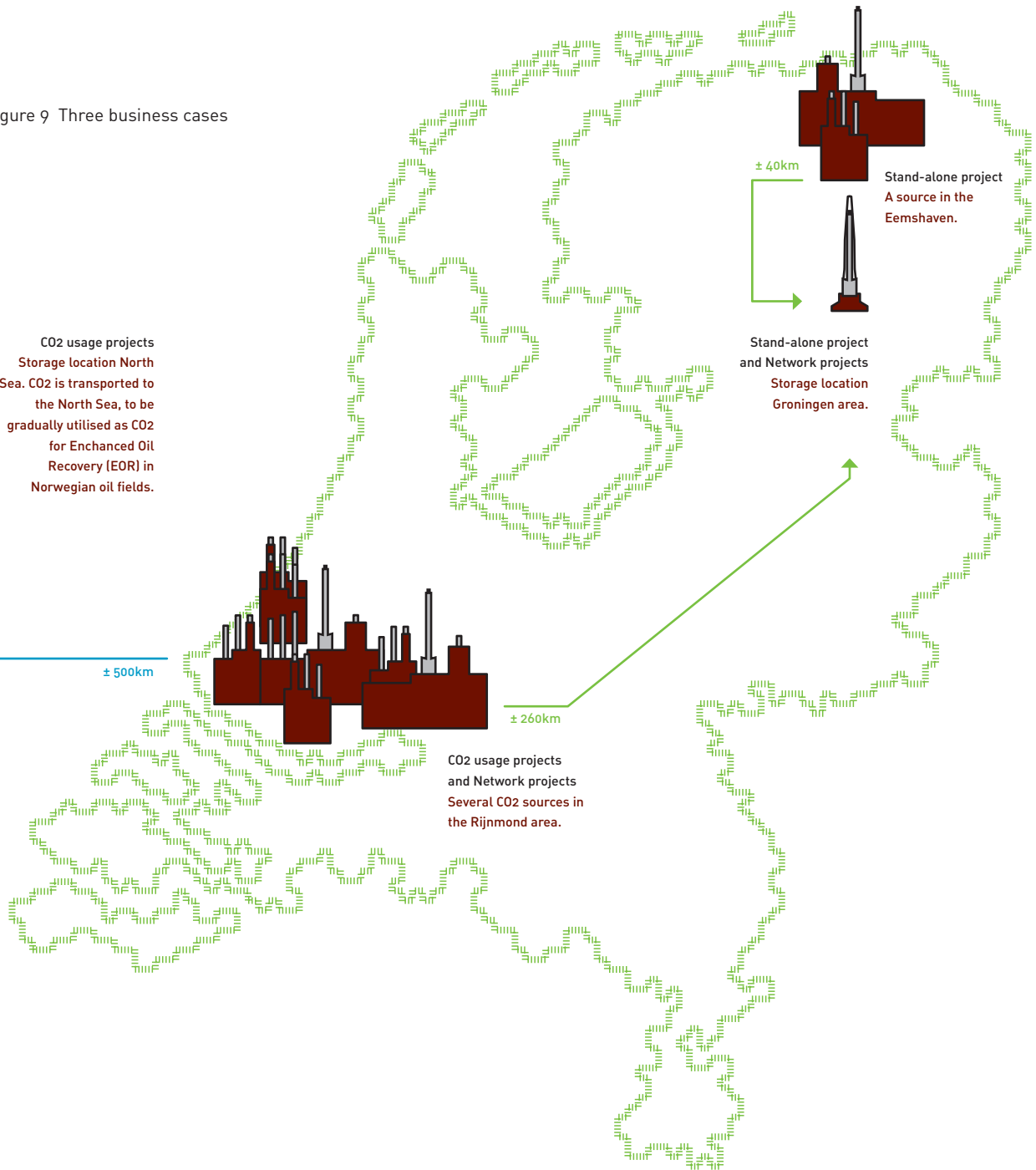


Figure 9 Three business cases

C02 usage projects
Storage location North
Sea. C02 is transported to
the North Sea, to be
gradually utilised as C02
for Enhanced Oil
Recovery (EOR) in
Norwegian oil fields.



- › Operating and maintenance costs;
- › The costs of augmenting power due to the loss of efficiency in the operating phase (make up power).

The extra costs for transport and storage include:

- › Investments;
- › Operating and maintenance costs.

Stand-alone business case

We chose the following project configuration for the island project. The CO₂ source is the IGCC plant planned by NUON in Eemshaven, in the north of the province of Groningen. The Eemshaven plant is scheduled to go into operation in 2011. The Annerveen¹ field was chosen as an appropriate storage location because the gas field in this area is expected to be one of the first to be depleted. Eemshaven and Annerveen are approximately 40 kilometres apart.

Network business case

Three CO₂ sources in the Rijnmond area were chosen for the network project. Two power plants are currently in the planning phase. The first one is an Electrabel 750 MWe PC plant which should be in operation by 2011 and the second is an E.ON 1080 MWe PC plant that will come on-line at about the same time. In addition, a 1100 MWe PC plant is planned for the Rijnmond area with a start-up date in 2020. Five gas fields in the Groningen area were selected for storage. These fields are expected to be depleted in the period 2015-2020. The distance between the CO₂ sources and the gas fields is approximately 260 kilometres.

¹ Annerveen | All the gas and oil fields in this study have been chosen on the basis of publicly available information about expected time of depletion. It is clear that there are many factors that could influence when and if they will become available for CO₂ storage.

Table 7 shows the most important results to emerge from an analysis of these business cases. Background information can be found in the Ecofys (2007) report.

4.4 EOR could help finance the development of a CO₂ network in the North Sea

Projects using CO₂ were also analysed in order to determine the extent to which EOR can help finance the first CCS networks. The three CO₂ sources in the Rijnmond area as described above in the network project were used for the CO₂ usage project. However, in this case the CO₂ is transported to the North Sea and stored in gas fields in the Dutch part of the North Sea. Later the CO₂ will be used for Enhanced Oil Recovery (EOR) in Norwegian oil fields approximately 500 kilometres from the Rijnmond area. (See also Figure 9).

It is more difficult to forecast the financial results of an EOR project. To a large extent the economics are determined by two parameters:

- › The amount of extra oil that can be recovered for each tonne of CO₂ that is injected. This parameter depends on many factors and can vary substantially from one field to the other. As yet it is impossible to make a sound forecast for this parameter in the North Sea situation. Based on available knowledge, a variation of between one and three barrels of oil for each tonne of CO₂ injected is realistic;
- › The value of a barrel of oil for the oil company depends on many factors and will vary from one country to another. For this study the value of €20/barrel was taken as an average value.

Integral CO₂ costs were calculated on the basis of the above parameters. The results are given in Table 8.

Table 7 Overview of the results derived from the two business cases: the stand-alone project and the network project

	Stand alone project	Network project
> Investment costs (M€)	315	1,500
> Total amount of CO ₂ stored (Mtonnes)	73	319
> Costs		
Average costs of capture	26	33
Transport	1	4
Storage	2	2
Total costs (€/tonne)	29	39

Table 8 Overview of the results for a network project including EOR ¹ on the North Sea

> Investment costs (M€)	3,600
> Total amount of CO2 stored (Mtonnes)	306.4
> Costs	
Average costs of capture	33
Transport	5
Storage	-2
Total costs (€/tonne)	36

¹ EOR | Enhanced Oil Recovery

Table 9 Variation in the total financial result based on yield increase of EOR ¹

	Yields (barrel/tonne of CO2)			
	1.5	2.0	2.5	3.0
> Costs				
Average costs of capture	33	33	33	33
Transport	5	5	5	5
Storage	-3	-9	-16	-22
Total costs (€/tonne)	35	29	22	16

¹ EOR | Enhanced Oil Recovery

Table 8 shows that the added value of using CO₂ for EOR is relatively small if there is a relatively low oil yield per tonne of CO₂ (1.3 barrel/tonne of CO₂). Table 9 indicates how the total financial result varies as yield increases. These results show that if yields prove to be higher than assumed in this study, EOR can significantly enhance the total financial result. What the actual yield is for each oil field is uncertain and highly site specific.

In this business case no account was taken of the fact that there could be other uses for CO₂, for example, in industry or in the greenhouse sector. It is clear that if a project includes extra usage possibilities - where prices per tonne of CO₂ can rise to €40 - the overall financial result will be much better even if the flows for these types of usage projects is relatively small. This shows that there is considerable potential for optimising the financial performance of CO₂ usage projects.

4.5 Expected prices within EU-ETS are between €20 and €50 per ton

As stated above the prices for EU allowances will probably provide the financial basis for CCS. Due to uncertainty about post-Kyoto policy it is impossible to provide an accurate forecast of allowance prices.

Market specialists have generated a range of CO₂ price projections for the period 2008-2012. Their low, medium and high projections are on average in the order of €5, €15, and €25/tonne CO₂ respectively. The climate policy scenarios used by the European Commission include more conservative projections for the year 2010, i.e. between €7.5 and €15/tonne CO₂. In each of these scenarios sharp increases in the coming decade are taken for granted. Assuming

that international climate policy and the EU-ETS will be prolonged and strengthened, there are good reasons to assume that CO₂ market prices will increase in the years following the Kyoto period.

Therefore, it can be concluded that by the year 2015 the CO₂ market price may be anywhere between €15 and €35/tonne CO₂. It is suggested that €25/tonne CO₂ could be used as a central value. By 2020, the range may be between €20 to €50/tonne CO₂, with €35/tonne CO₂ as a central value.

In order to make CCS financially feasible, the price for CO₂ within EU-ETS will need to reach a permanent level of €30 per tonne in order to make the implementation of CCS in IGCC plants possible. EU-ETS prices will need to be permanently around the €40 per tonne mark or above for Pulverised Coal plants (PC). Price volatility in EU-ETS or uncertainty about future price developments are likely to delay or prevent investments in CCS.

- › Implementation of CCS requires long-term policy commitments.

5

- › Dutch policy on CCS needs to be developed within the context of the EU ‹
- › All legal issues related to CCS must be resolved ‹
- › Policy and market conditions should ensure that new power plants are capture ready ‹
- › It must be clear what capacity will be available and when ‹
- › Instruments that help reduce the financial risks of CCS need to be developed ‹
- › The government should clarify how maintenance and monitoring will be organised after CO₂ storage sites have been abandoned ‹

5 Implementation of CCS requires long-term policy commitments

5.1 Dutch policy on CCS needs to be developed within the context of the EU

Currently, CCS occupies a key position within Dutch policy. Politicians see CCS as a (intermediate) solution to current climate problems. The business concepts presented in chapter 4 demonstrate that - in order to include CCS successfully in Dutch policy - it is important to set certain preconditions:

- › Clear CO₂ targets and time paths for reductions;
- › Continuation of EU-ETS;
- › A place for CCS with EU-ETS;
- › Clear and harmonised allocation rules within ETS;
- › A similar approach towards CCS in all EU Member States.

Required action by the government:

- › Listed preconditions require a European approach or a strong lobby from Dutch politicians in Europe. When these preconditions are met, a level playing field will be established in which power producers and industry will feel confident enough to commit themselves to invest in CCS.

5.2 All legal issues related to CCS must be resolved

During the investigation of CCS, several open issues within the current Dutch legal framework were identified. These will need to be resolved in order to make CCS possible in the Netherlands. An overview of these open issues is provided below together with suggestions about possible ways in which the legal framework could be adjusted.

Capture

As far as the capture of CO₂ is concerned, there appears to be no legislation that needs to be adjusted or changed.

Transport

Transportation of CO₂ by pipeline is not included in the legal framework for pipelines. For onshore pipelines in general, adjustments are being made to current legislation, including that which covers technical requirements, spatial planning and external safety issues.

In 2008, a new 'Algemene Maatregel van Bestuur' (AMvB) will be presented by the Ministry of Environment that will include the transportation of CO₂. This new legal framework should include all the elements necessary to facilitate the introduction of CO₂ transport.

No adjustment is needed to the current legal framework for offshore pipelines.

Storage

The Mining Act provides a good basis for CO₂ storage. However, in order to be able to implement CO₂ storage on a commercial scale in the Netherlands, it will be necessary to implement regulatory schemes that define risk assessment procedures

Adjustments needed to the current legal framework for onshore pipelines:

- › The newly developed 'AMvB' should include safety requirements for CO₂ pipelines and a definition of the level of contaminants in the CO₂ stream that would be technically and socially acceptable;
- › Clarity on the Environment Impact Assessment (EIA) requirements of (long) pipelines;
- › Clarity on the risk profiles for CO₂ pipelines.

Necessary adjustments to the current legal framework for storage of CO₂:

- › Development of a regulatory scheme that defines the procedures required for risk assessment, including safety and/or performance criteria,

in more detail. In particular, a proper assessment of long-term impacts (within the framework of the Environmental Management Act) requires input (e.g. criteria for the probability of leakage) from the performance assessment that is made within the framework of the Mining Act.

The fact that different permitting authorities - the Ministry of Economic Affairs, Ministry of Environment and the Provinces, amongst others - are legally responsible means that close cooperation is necessary to ensure that the long-term impacts of CCS are assessed accurately. The necessary adjustments to the Environmental Management Act and the Mining Act could be made if a protocol that included safety and/or performance criteria was developed. This protocol could describe the workflows and methods agreed to by the relevant authorities and operators and thus clarify existing legislation.

5.3 Policy and market conditions should ensure that new power plants are capture ready

The current legal framework does not include any reference to the capture readiness of power plants that have not yet been built. In order to meet the climate goals set by the Dutch government and based on the assumption that CCS can play a role in meeting these goals, government and power companies need to start developing clear criteria for capture readiness and to ensure the inclusion of these criteria in current legislation.

in relation to legal frameworks (Mining Act and Environmental Act);

- › Clarity in the Mining Act on legal issues with respect to production licences (e.g. of natural gas) and storage licences (of CO₂): long-term liability, ownership and abandonment;
- › Apply the 'Rijkscoördinatieregeling' of the Spatial planning Act to CO₂ storage in order to ensure transparent organisation of both national and local licences;
- › CO₂ storage to be included in waste regulations.

Necessary action to be taken by government and CO₂ emitters:

- › Defining capture-ready criteria and including these criteria in the current legal framework or the signature of a Memorandum of Agreement between power companies and the government on this issue.

5.4 It must be clear what capacity will be available and when

There is still a high degree of uncertainty about when the various Dutch gas fields will be depleted and whether they will become available for CO₂ storage. There is likely to be fierce competition around the issue of gas storage. As long as uncertainty prevails, network companies will not embark on the most time-consuming aspect of CCS projects – network building. The whole process of implementing CCS would benefit if there was more certainty about the projected storage capacity. The government – within the framework of the Mining Act - has jurisdiction over the companies producing gas in the Netherlands. As such it needs to play an active role in ascertaining the amount of storage capacity potentially available. Clarity is also needed on abandonment procedures, including the timing of abandonment and the permits required.

Actions that the government should take:

- › Provide clarity on the availability of CO₂ storage capacity in the Netherlands;
- › Adjust the Mining Act in order to enable the withdrawal of part of production licences in areas where production activities have stopped to give third parties the opportunity to submit applications for a storage licence;
- › Provide clarity about abandonment procedures;
- › Allocate named (depleted) gas fields for CO₂ storage;
- › Use existing networks, for example, those of the Ministry of Defence.

5.5 Instruments that help reduce the financial risks of CCS need to be developed

Because of the high level of investment required for capture and the long pay-back times involved, it is expected that parties will be reluctant to invest in capture if CO₂ prices are not high or stable enough. As long as there is no long-term certainty about allocations within the EU-ETS, prices will remain uncertain. The implementation of CCS could be accelerated if there was a financial instrument that guaranteed a price for the emission reductions generated by CCS.

Possible action by the government:

- › Ensure - through climate policy - a stable CO₂ price above €30-40 per tonne;
- › Develop financial instrument(s) that reduce (temporarily) the financial risks associated with CCS investments until stable price levels have been reached;
- › Develop a transport infrastructure;
- › Encourage European cooperation for large-scale investments (e.g. an offshore pipeline network).

5.6 The government should clarify how maintenance and monitoring will be organised after CO2 storage sites have been abandoned

Whichever concept is adopted, there will always be a role for government in maintaining and monitoring fields once they have been fully filled. This role also includes a form of liability if leakage occurs. The monitoring system applied will depend on local conditions, the reservoir and the injection scheme. Monitoring will include the reservoir/aquifer and its overburden, wells, shallow subsurface and the atmosphere. In addition monitoring will also cover ground movements and induced seismicity.

Necessary action by the government:

- › Clarity is needed on how the maintenance and monitoring of a CO2 storage site will be organised;
- › The risks and liabilities after completing storage need to be clarified.

- › Implementation of CCS requires a strategic technology investment plan.

6

- › Power companies need to invest in making new power plants capture ready ‹
- › Capture demonstration projects are necessary to demonstrate the technology on a commercial scale ‹
- › Technology development, especially related to solvents, needs to be followed at the international level ‹
- › Funds need to be made available by the government for necessary technical developments ‹
- › Funds are necessary to facilitate initial investments in CO₂ networks, both on and offshore ‹

6 Implementation of CCS requires a strategic technology investment plan

6.1 Power companies need to invest in making new power plants capture ready

In previous chapters it has been clearly stated that implementing CO₂ capture in an existing power plant will only be cost-effective if these plants are already capture ready. Power producers in the Netherlands are currently planning to build several new coal-based power plants. These will be mainly PC plants. To ensure that large-scale CCS will be possible by 2020, it is essential that all new Dutch power plants are capture ready.

Required action by CO₂ emitters:

- › Adopt a definition of capture readiness, for example the IEA guidelines;
- › Ensure commitment by power producers to make new plants capture ready;
- › Participate actively in EU initiatives such as the planned Zero Emission Platform demonstration projects.

6.2 Capture demonstration projects are necessary to demonstrate the technology on a commercial scale

Post-combustion capture has not yet been tested on a commercial scale. Before it is implemented in plants, proof of principle should be demonstrated on a scale that compares realistically with a commercial

Necessary action by power companies:

- › Plan and implement early demonstration projects for both pre-combustion and post-combustion capture technology.

plant. Such a project – from planning phase to project evaluation – will take at least five years to complete.

A demo is also recommended for pre-combustion. Adding a shift reactor to an existing IGCC plant would make it possible to assess the consequences of pre-combustion capture on energy consumption and the influence of a larger amount of hydrogen in the syngas on the flame stability of the gas turbine.

6.3 Technology development, especially related to solvents, needs to be followed at the international level

Most new power plants in the Netherlands will be PC plants. Solvent technology can play an essential role in determining the cost of capture in PC plants. Over the coming five to ten years substantial improvements are projected in solvent quality. A significant international R&D effort is required to actually deliver these improvements. As far as CCS in the Netherlands is concerned progress in this area should be followed closely to ensure that Dutch plans stay in line with developments taking place internationally.

- Necessary action by all stakeholders:**
- › **Dutch R&D programmes such as CATO should be maintained and linked to international developments.**

6.4 Funds need to be made available by the government for necessary technical developments

Before CCS can be implemented in the Netherlands, it will be necessary to carry out large-scale demonstrations of post-combustion capture and capture in an IGCC plant. This will require government funding. Such project demonstrations will be important for all post and pre-combustion capture projects in the Netherlands. Funding by government is essential since there is no clear commercial advantage for those that will implement these demonstration projects.

- Required action by the government:**
- › **Funding for R&D, demonstration and risk mitigation over the next decade is required - typically costing more than €100 million per year.**

6.5 Funds are necessary to facilitate initial investments in CO2 networks, both on and offshore

The time needed to get projects operational is governed by the time needed to produce the pipelines in each of the concepts presented here. In the network concept, particular pipelines will probably need to be planned and built before there is full certainty about all the sources and sinks to be connected. This means that the pipeline operators will need to take a certain amount of investment risk. The government, but also local players such as harbour authorities, could help reduce some of these risks by participating in a network organisation. This is probably even more important in offshore networks. The potential for offshore storage is great and, if EOR proves to be profitable, offshore storage could be substantially cheaper than storage in gas fields. However, the costs of offshore pipelines are higher than those onshore and - because of the international dimension - there are higher financial risks as well.

Necessary action by the government and local authorities:

- › **Structure a funding programme to help develop a CO2 transport infrastructure.**

- › Implementing CCS is an organisational challenge.

7

- › An organisation is needed to take responsibility for implementing the necessary steps ‹
- › Timing is critical to achieve the objectives ‹
- › Close cooperation and support for consortia preparing CCS is essential ‹

7 Implementing CCS is an organisational challenge

7.1 An organisation is needed to take responsibility for implementing the necessary steps

The previous chapters list the issues that need to be resolved in order to ensure that CCS is implemented on a large scale by 2020. Resolving these issues will require the active participation of all those involved: government, power producers, industry, exploration and production companies and gas transportation firms. It will also require active cooperation and coordination between them. To ensure that all activities are coordinated, monitored and if necessary, adapted as new insights arise there must be an organisation capable of taking responsibility for all of these tasks. This organisation - which could be called the CCS implementation agency - would be responsible for the actual implementation of CCS. It would differ from other organisations in the sector because its focus would not be on uncertainties and research needs but rather it would create the

Necessary action by the government:

- › **Establish a CCS implementation agency that is responsible for creating the necessary preconditions for the large-scale implementation of CCS in the Netherlands.**

conditions for concrete solutions. If this type of implementing agency is not established, there is the risk that those involved will simply focus on their own priorities and the overall objectives will not get sufficient attention. The advantage of an implementing agency is that it would be able to remove generic obstacles related to legal issues as well as research.

The agency should play several roles:

- › Develop a long-range plan designed to ensure large-scale implementation of CCS by 2020;
- › Determine to what extent critical issues are covered by existing national and international programmes;
- › Initiate activities that have not yet been started by other parties;
- › Monitor progress in all relevant fields and - if necessary - update the long-range plan;
- › Provide a knowledge base for all stakeholders.

The proposed agency will probably need to be initiated by the government but there must be strong cooperation among all stakeholders. The agency will probably also be governed by these stakeholders.

7.2 Timing is critical to achieve the objectives

The previous chapters describe the steps that need to be taken to make large-scale CCS feasible by 2020. It is also important, however, to look at the interrelationship between these steps over time. Figure 10 provides a time plan that clearly shows which steps need to be taken in order to meet the 2020 deadline. The blue lines refer to the interdependency of the individual steps.

The plan shows that most preparatory steps must be completed by 2012. It will then be possible to embark on realising a large-scale stand-alone

- › **Required action by the implementation agency:**
 - › **Facilitate and monitor the timing of the necessary actions in order to achieve large scale implementation of CCS in the Netherlands by 2020.**

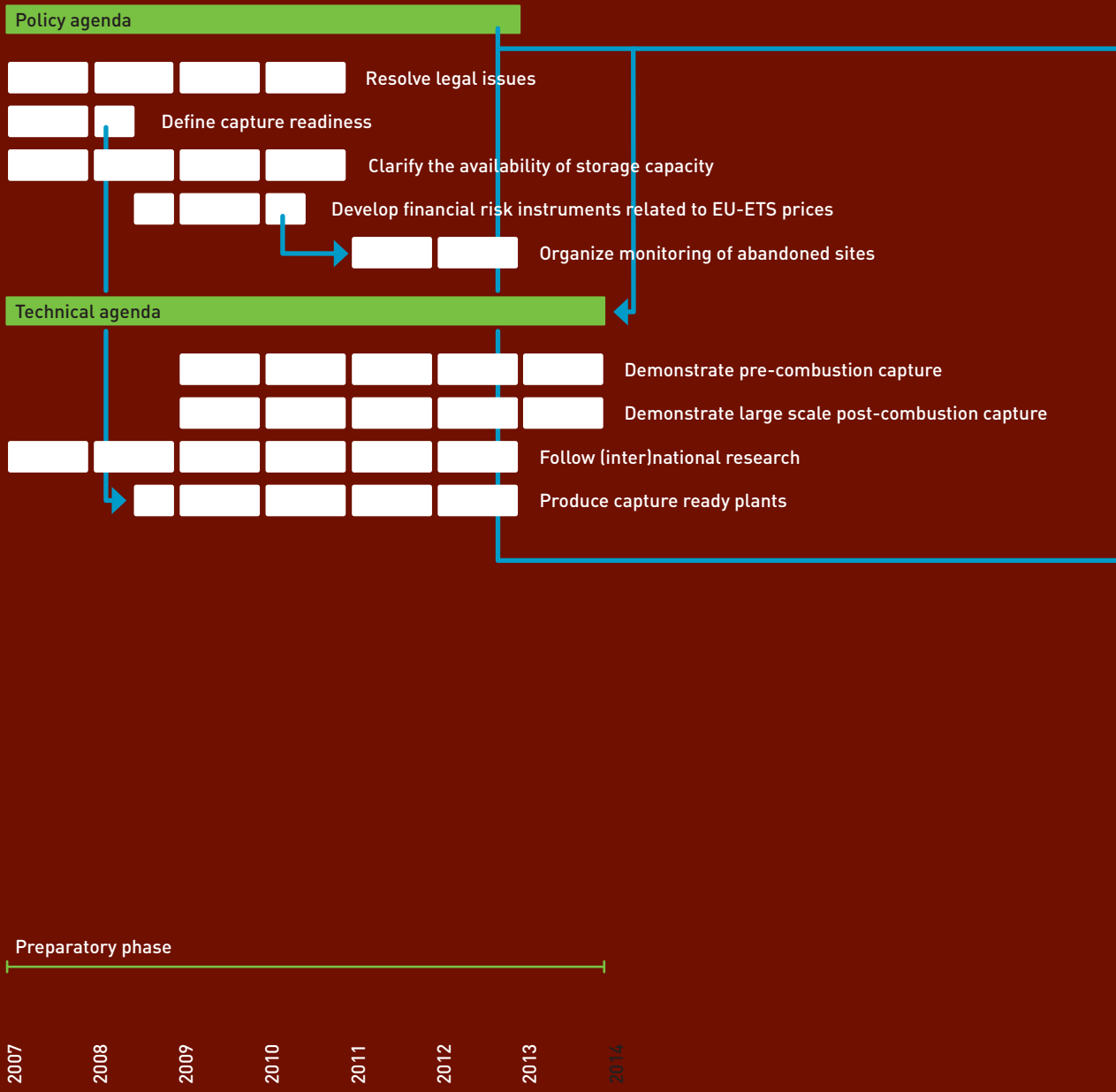


Figure 10 Timeline for implementing CCS, including preconditions

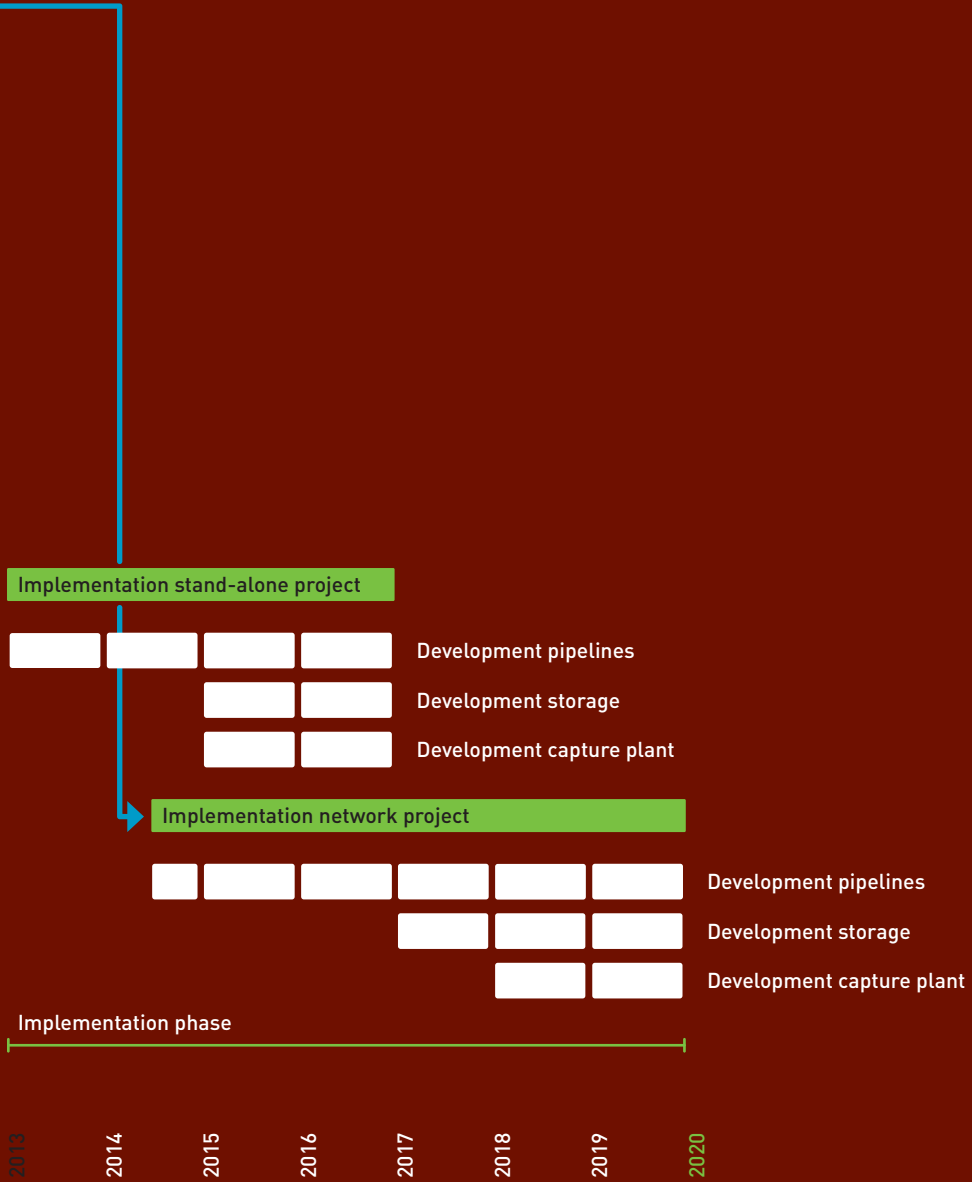
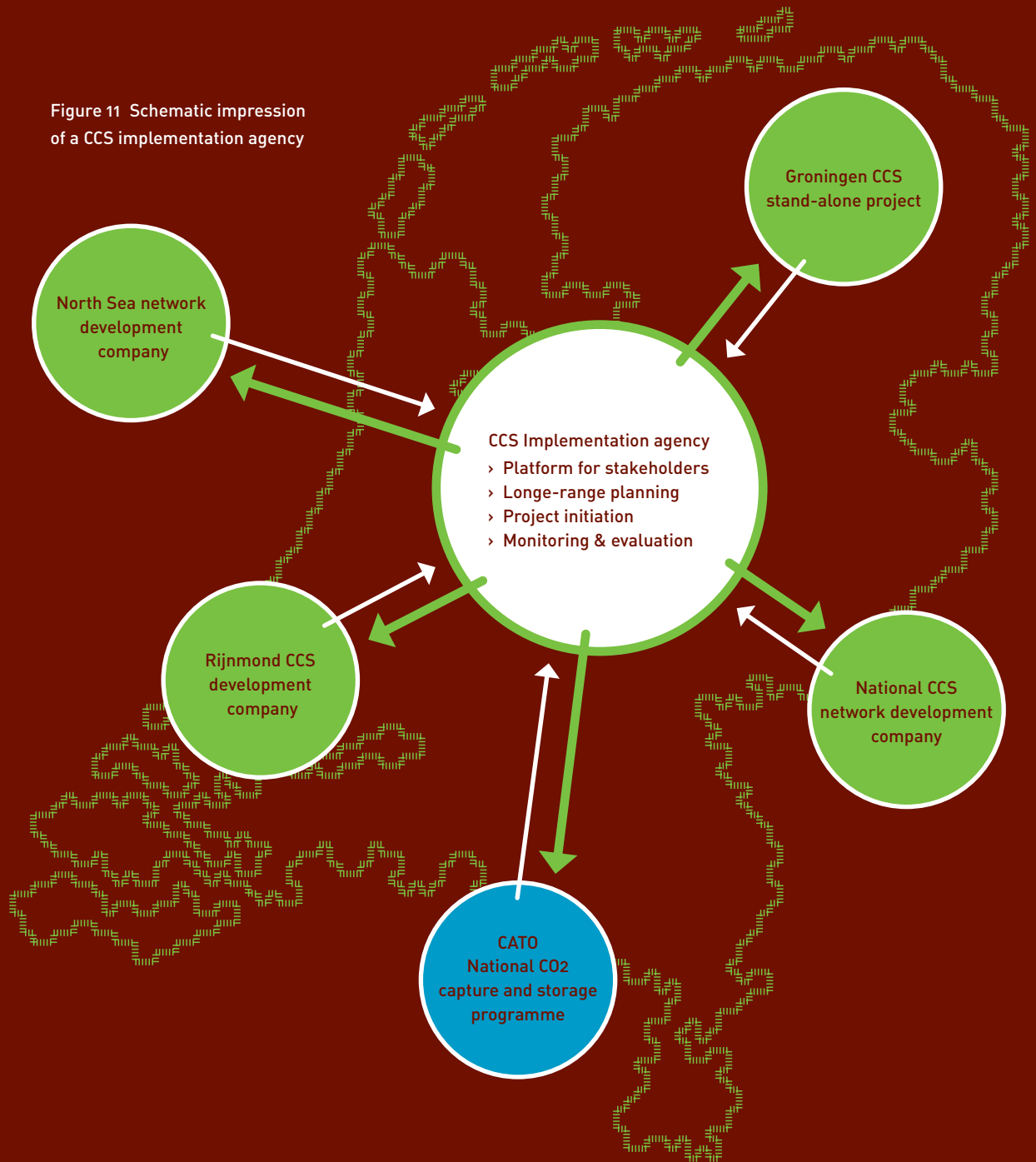


Figure 11 Schematic impression of a CCS implementation agency



project that would come into operation in 2016. Work on a network project could begin in 2014 and it could be operational by 2019. An early start with the preparatory phase is necessary to realise large scale storage by 2020.

7.3 Close cooperation and support for consortia preparing CCS is essential

The CCS implementation agency described in section 7.1 will be responsible for all the generic pre-conditions necessary for starting CCS. This agency, however, will not be responsible for the actual implementation of CCS projects.

The CCS projects will need to be undertaken by consortia of a range of companies. For projects to be operational in 2020 it is essential to start developing these consortia early. However, given the current market situation, it is unlikely that these consortia will start up without the support of the national and local government. This support could be organised by the central implementation agency.

The central agency and the development consortia should form a network. This would enable the consortia to communicate the generic obstacles to the central agency and make it possible for the central agency to communicate solutions to the consortia. Figure 11 shows the interaction between the various organisations and their relationship with the Dutch CATO CO₂ capture and storage research programme. Close cooperation with researchers in this field is essential.

- Necessary action by all stakeholders:**
- › **Initiate a network of CCS initiatives in the Netherlands (to be coordinated by the CCS implementation agency).**

In-depth studies referred to within this investigation of CO₂ capture, storage and transport in the Netherlands

- › Investigation of CO₂ storage; strategy for CO₂ capture, KEMA 2007.
- › Transportation of CO₂ in the Netherlands, Ecofys 2007.
- › Options for CO₂ storage in the Netherlands; Time-dependent storage capacity, hazard aspects, and regulations, TNO 2007.

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