Utrecht Centrum voor Energie-onderzoek
Utrecht Centre for Energy research

CATO:
A five-year research project in the area of CO_2 Capture, Transport and Storage in the Netherlands

Executive Summary

Background

The present world emission of CO_2 is around 25 gigatonnes/year and is still increasing. The evidence for the influence of these emissions on the global climate is becoming stronger and stronger. Most scientists agree that in order to stabilise the CO_2 concentration at twice the pre-industrial level, i.e. at 550 ppm, the worldwide CO_2 emissions have to be reduced with more than 50%. In 1997 concrete targets have been formulated in Kyoto for the gradual reduction in emissions. The required reductions in emissions (which are dominated by CO_2 but also involve other greenhouse gases) can be realised by means of an integrated package of three groups of measures (Trias Energica):

1. Energy efficiency improvements (including efficient use of materials);
2. Use of renewable energy sources, which emit no (or little) CO_2;
3. Clean use of fossil fuels, by capturing and storing CO_2 before it is being released to the atmosphere.

In many countries considerable efforts are undertaken to promote energy efficiency measures and an increased use of renewable energy sources. At the same time it is becoming clear that the combined effect of energy efficiency and renewables cannot yet achieve the required reductions in emissions alone.

It can be concluded that “decarbonisation” of fossil fuels may also be required to reach the required stabilization of the CO_2 concentration in the atmosphere, in bridging the gap to a fully renewable energy system. This is why in many countries research and demonstration projects are initiated in the area CO_2 capture, transport and storage, and to study the risks and limits of the various technologies. The present CATO project aims at building a strong knowledge network in this field in the Netherlands, to be well prepared for the possible implementation of this option.

Problem definition

It is estimated that, in order to stabilize the atmospheric CO_2 concentration at 450-550 ppm, it may be required to capture and store hundreds of Giga-tonnes of CO_2 worldwide from energy conversion processes in the period between 2010 and 2100.

Research in the past ten years, also by partners of the CATO network, has shown that CO_2 sequestration has a large potential for the efficient and cost-effective reduction of the emission of CO_2. The worldwide CO_2 storage potential is very large (IEA-GHG):

- Depleted oil and gas reservoirs: 920 Gt CO_2 (45% of world emissions until 2050)
- Deep saline aquifers: 400 – 10,000 Gt CO_2 (20 to 500% of world emissions until 2050)
- Unmineable coal beds: > 15 Gt CO_2
- Deep ocean: probably very large (order > 100,000 Gt CO_2) but disputed

According to the Netherlands National Environment Plan (NMP-4) the CO_2 emission in 2030 will have to be reduced by 120 Mton CO_2 per year in order to achieve a 30% reduction compared to the emission in 1990. For the clean fossil fuel option a possible contribution of 50-60 Mton CO_2 has been estimated. This implies that, even if the objectives for the contributions of energy efficiency and renewables are met, in this decade already a start has to be made with the actual storage of CO_2 in order to reach the required level in 2030. This also contributes to the transition to a fully renewable energy supply, amongst others through the use of hydrogen as an energy carrier.

Scientific relevance

Creating a network and knowledge infrastructure in the Netherlands to better understand and support a complex long-term transition process towards large scale deployment of Clean Fossil Fuel (CFF) systems on longer terms – if viable from an economic, social and ecological perspective - is a novelty in itself. A prime characteristic of the CATO project is that all major stakeholders and a number of research groups from very different fields of expertise are working together on the common objective formulated above, within an integrated framework. This is essential, because the implementation of these systems depends (potential) performance and impacts of all components of the system, from primary fuel up to the use of the final energy carrier and the final treatment of waste products like CO_2.

So far different institutions in the Netherlands, often from very different perspectives, have worked on a number of aspects or components of CFF systems. CATO wants to streamline the objectives and perspectives of these activities and integrate them into a comprehensive programme and network, closely connected to international networks in which the partners of CATO participate. Also it aims to assess and develop new knowledge, technologies and approaches for clean fossil fuel use, especially relevant for The Netherlands.
The different work packages described in this proposal contain a variety of in depth and sometimes monodisciplinary research. However, a number of research questions in these packages will be addressed by a variety of parties and disciplines. Integrating tasks - in particular WP 1 (‘system analysis, infrastructure and transition’), but also WP 5 (‘monitoring, safety and regulations’), WP 6 (‘communication’) and WP7 (‘management and knowledge transfer’) - will provide an integrating level where specific knowledge and expertise is combined, with major inputs from work packages WP2 (‘capture of CO_2)’, WP3 (‘underground storage of CO_2’) and WP4 (‘storage of CO_2 by mineralization’).

For the international arena, such a national programme and involvement of parties would be a rather unique. On the national level, CFF has received limited attention in the period 1995-2000 and the forefront position the Netherlands had in the world in the beginning of the nineties has deteriorated. Over the past years, there has been no coherent national programme. However, the scientific and industrial capacities in the Netherlands in the field of CFF are still of top quality. It is of vital importance to bring together the key partners in the Netherlands in a targeted CFF research programme. This is exactly what the CATO programme will do.

Economic and societal relevance

A couple of key challenges emerge from the current situation regarding sustainable use of fossil fuels focused on CO_2 capture and storage:

- It is not clear what criteria should be applied to CFF systems before they are considered sustainable and desirable from various perspectives (economic, social, ecological, etcetera). This hampers activities with CFF systems and demonstration of options on the short term and makes it unclear to what extent CFF can play a role in the future energy system.
- The very large number of systems possible combining a wide variety of capture, storage and infrastructure options for various sectors in the economy, makes it difficult to determine what options are most promising or desirable.
- In particular for underground storage a multitude of questions are not answered satisfactory with respect to storage potential, safety and ecological risks as well as the accessibility of storage sited for CO_2 injection under vary different conditions.

More specifically with respect to the knowledge infrastructure in the Netherlands it can be stated that:

- The potential of the Netherlands is underutilized, both in terms of geological opportunities (e.g. CO_2 storage in - nearly - depleted natural gas fields and coal beds, and recovery of methane by CO_2 injection) and economic structure (existence of a large heavy industry sector and a well developed energy infrastructure for natural gas, partly for hydrogen).
- The knowledge institutions, relevant university groups and a variety of industries (including a number of important global players) offer an outstanding array of research and development capacity relevant for CFF systems, but this knowledge is poorly organised. In addition, CFF systems has received relatively poor support in the Netherlands over the past 8 years or so, while the Netherlands as a whole had a frontrunner position in the world in the beginning of the nineties. The current situation is that the level of expertise and capacity in the Netherlands is still of high quality but rapidly losing ground compared to international developments.

The strategic results of the CATO project are found in the following areas:

- The deployment of various CFF systems can lead to improved stability and security of energy supply due to a shift from oil to coal, natural gas and unconventional resources such as ECBM. Provided CFF options meet a wide array of sustainability criteria (which is a key objective for the CATO project), they could cover over 50% of the total energy supply of the Netherlands (as well as in many other countries) in 2030-2050. This means that knowledge on CFF options is of strategic importance for energy security and supply and the planning of energy infrastructure on (supra-) national scale.
- CFF options could become responsible for the bulk of GHG emissions reductions halfway this century at a low cost level. Provided that a set of essential criteria is met, CFF may prove to be an essential approach towards an effective climate protection policy. Assuming 40 - 80 Mton CO_2 emissions are avoided per year at 50 Euro/ton CO_2 for expensive options (as would be the case for parts of the renewables and part of the energy efficiency improvement options) compared to potentially 20-30 Euro per ton CO_2 for advanced CFF options a cost saving in the order of magnitude of 1 – 2 Mld Euro per year might be achieved.
- Additional environmental benefits like strongly reduced NOx, SO2, CO and dust emissions can be obtained throughout all key sectors of society (this is in particular true for the use of hydrogen - produced from fossiel fuels combined with CO_2 capture and storage - in transport and industry) when appropriate CFF systems are deployed. Emission reduction of non-greenhouse gases in for example transport could be 90% or more.
- The Netherlands has specific advantages (NG infrastructure, many gas fields, aquifers, large heavy industry) for implementation of CFF options, which can give this country a strong comparative benefit compared to many other nations.
- Major opportunities for industry and energy system for demonstrating, developing and exporting new technologies to other parts of the worlds. With a programme as CATO, the Netherlands could remain on the cutting edge of this field.

The CATO project itself will contribute to those societal, strategic and environmental benefits by a long list of key deliverables and results.
The role of market parties in developing and deploying CFF systems is so far very limited exactly because of various strategic uncertainties (questions concerning the ecological sustainability, costs, competitiveness, national and international policy development, social acceptance, uncertainties with respect to underground storage, improvement potential of different options, and the identification of robust options) and because many advanced systems and technologies are in a pre-commercial stage. Therefore, government support (as is possible through the ICES-KIS funds) is highly desired.
CATO presents a list of coherent activities to assess, develop and explore CFF systems that can be applied to achieve a sustainable energy future in the Netherlands; setting up a coherent and interlinked knowledge infrastructure is a pre-requisite to do so.

Project implementation

The CATO project is structured in seven distinct work packages, as described in the table below:

WP	Subject	WP Leaders
1	**System analysis & Transition**	**UU-Copernicus** **Ecofys**
2	**Capture of CO_2** **2.1 Post-combustion** **2.2 Pre-combustion** **2.3 Denitrogenated conversion**	 **TNO-MEP** **ECN** **TNO-MEP**
3	**Storage of CO_2** **3.1 Storage gas fields** **3.2 Storage coal fields (ECBM)**	 **TNO-NITG** **Shell (SIEP)**
4	**Mineralisation** **4.1 Subsurface mineralisation** **4.2 Surface mineralisation**	 **Shell (SIEP)** **TNO-MEP**
5	**Monitoring, safety and regulations**	**TNO-NITG**
6	**Communication**	**Leiden University**
7	**Management and knowledge transfer**	**UU-UCE**

Project consortium and cooperation

The main proposer is the **Utrecht Centre for Energy research.** UCE is a collaborative research centre in which 6 groups of Utrecht University and 4 external partners (ECN, RIVM, REMU and Ecofys) cooperate in the area of long-term multidisciplinary energy research.
The following institutions or companies are participating in the CATO proposal:

Companies
Shell International Exploration and Production (SIEP)
NAM, Nederlandse Aardolie Maatschappij
KEMA (Note: the six Dutch electricity generating companies (Delta, Electrabel, E.ON, Essent, Nuon Power and Reliant) participate via KEMA
NV Nederlandse Gasunie
Ecofys BV
EBN (Energie Beheer Nederland)
Research institutions
ECN (Energy research Centre of the Netherlands), Business Unit Clean Fossil Fuels

TNO-MEP (Environment, Energy and Process Innovation)
TNO-NITG (Netherlands Institute for Applied Geology)
Universities
TUD, Technical University Delft, Fac. CITG, Afd. Technical Geosciences
UL, University Leiden, Group Energy and Environmental Research, section Social & Organisational Psychochology.
UT, University Twente, Dept. Chemical Technology
UU, Utrecht University, Copernicus Institute
UU, Utrecht University, Faculty Earth Sciences
UU, Utrecht University, Faculty of Chemistry, Section Inorganic Chemistry
Environmental organisations
Netherlands Society for Nature and Environment
Greenpeace (Netherlands)
WNF, World Wildlife Fund (Netherlands)

The Utrecht Centre for Energy research is the coordinator of the CATO project and responsible for internal and external coordination, management of the organisation and the budget of the project, handling of the Bsik subsidy, and reporting to Senter and the Steering Committee of the project.

Each member of the CATO consortium nominates one representative in the CATO Steering Committee. The Steering Committee has the authority to take binding decisions with respect to the activities undertaken in the project.
The Steering committee nominates Work Package leaders, upon a proposal by the coordinator. The Work Package leaders are responsible for the progress and quality of the work to be undertaken in their Work Package, as formulated in the CATO project plan.
Each member of the CATO consortium nominates a projectleader for its own part of the work within the CATO project. The project leader is responsible for the progress, quality and budgeting of the work to be undertaken by his/her organisation, as formulated in the CATO project plan and detailed in an annual Project Plan of Activities.
A CATO Scientific Advisory Board is formed to support and advise the coordinator and Steering Committee.

Dissemination and transfer of knowledge

In this project the dissemination of knowledge is not a one-way process, but, given the heated debates about the broad range of aspects in cleaning fossil fuels, always a two-way process. This particularly holds for the environmental organisations in the CATO consortium, which have clearly stated that in the energy sector their priority lies with energy efficiency and renewable energy sources. As described in the Background of this Summary the climate problem can probably not be solved by these two alone, so cleaning fossil fuels will probably be required as the third option, but under strict conditions of safety, etc. Asking unusual questions, such as put forward by Greenpeace, should be one of the conditions in participating in this project and undoubtedly will lead to new viewpoints within the research community, possibly leading to a reorientation of the research during the project.

The scientific work to be undertaken in the CATO project will generate a series of publications in scientific journals. This is a standard process within the university groups within the consortium and requires no direct involvement of the management.
Translation of those research results into messages in easily understandable language, bringing them into discussions at workshops with stakeholders and making them widely available (through leaflets, a website or by other methods) is regarded as a key responsibility of the CATO

management. To this end a CATO website will be established by UCE and maintained regularly, with requests for inputs from the CATO partners.
At the same time existing networks, such as the EU network CO2NET from which UCE and other CATO partners are a member, will be used as an effective channel to share the knowledge generated in CATO with other European partners.

Finances: budget and coverage

The total CATO project is budgeted at 29.4 M€, of which 25.4 M€ are project costs applicable for a Bsik subsidy of 12.7 M€. An agreement between the partners has resulted in the creation of a socalled equalizing fund: a certain percentage (22.7%) of the Bsik subsidy is redistributed over the partners, in order to cover the costs of for example university work with little own funding. The budget clearly shows that CO2 capture is at the heart of the CATO proposal, with more than 40% of the budget. Some of the industrial contributions are hidden in the budget. Shell (SIEP) for example covers part of the costs of the research at TU Delft, and also the costs of a PhD student at the Department of Earth Sciences at Utrecht University.