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CCS: the next technological lock-in?
A case study from The Netherlands

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Carbon Capture and Storage (CCS) is now propagated widely by policy makers, NGOs, and academics as a quick mitigation option for the large-scale curbing of greenhouse gas emissions. Its quick emergence in the last 3-4 years stands in shrill contrast with the decades-long slow emergence of renewable energy options and energy conservation. Moreover, CCS is sold as a 'bridge' or 'transitional' technology to 'buy time' for a large-scale transition to sustainable energy generating options.

In this paper we will criticize this emerging paradigm, using the Dutch (and possibly a few other countries') case as an example. CCS should rather be conceptualized as a new strategy by incumbent fossil fuel industries to consolidate their grip on the market. The concept of bridge or transitional technology is unknown in technology dynamics and innovation studies. Rather than being a 'bridge' technology, large-scale investments in CCS installations will prove to help continue the fossil fuel trajectory and hamper the development of alternatives. Its quick rise to prominence is an indicator for a renewed 'lock-in' of fossil-fuel based energy technologies.

Rather than massive large-scale investments in CCS, this paper pleads for a cautionary approach of multi-stakeholder experimentation and learning, keeping in mind that CCS should only be used where other options are not feasible, possibly in countires like India and China. Development for those markets should be a co-development together with European and US countries and companies. For the US and Europe however, CCS will hamper the quick and large-scale development of renewables, many of whom are market-ready or nearly so.

1. Introduction

In this paper I will discuss the history, the current situation, and the future of CCS in The Netherlands. First I will sketch as a context the history and present of Dutch environmental, energy, and climate policies, including present policies on CCS. Next I will concentrate on some regional developments, especially in the port of Rotterdam, which are important and relevant for the Dutch CCS developments. CCS in the Netherlands cannot be separated from the discussion on new coal power plants: three or four of those are presently planned for The Netherlands; they are heavily criticized by Greenpeace. The developments of CCS have been greatly stimulated by the CATO research program, which I will describe next. After a section on the present situation and the future of CCS I will concentrate on

public perception and acceptance, both theoretically and empirically. Finally I will reflect on these developments from a technology dynamics point of view, asking the question if and how CCS is a lock-in for fossil fuels[1].

The Netherlands is a country of 16.4 million inhabitants (2007), and is a founding member of the European Union. Its BNP is about € 500 billion (2006) and its ranking on the Human Development Index 2005 is 9th (0.953). The Dutch economy is mainly a service economy (73%). Its main industries are agriculture including horticulture, metal industry and machine building, electrical appliances, chemical industry, oil refinery, construction, micro-electronics, fisheries.

Its main sources of energy are domestic and imported natural gas for heating, imported oil for transportation and for the (petro)chemical industry; imported coal, natural gas, (mostly imported and some domestic) nuclear energy for electricity generation, and some biomass and other renewables. Since in the 1960s a huge natural gas field was discovered and exploited (the 'Slochteren' field in the North-East), the Netherlands had its first domestic major source of energy since the closing of the Limburg coals mines, also in the 60s of the previous century. Because of this former coal mining and recently discovered gas fields, the Netherlands, and especially the Delft University of Technology and Royal Dutch Shell Company, have a lot of knowledge about geology and mining. The Dutch Slochteren gas is exploited by the NAM (Nederlandse Aardolie Maatschappij; Dutch Fossil Oil Company), a 50-50 joint venture of Shell and ExxonMobil.

The NAM produces each year about 55 billion m3 gas; about 35 b. m3 of it comes from the Slochteren field; NAM provides about 75% of Dutch gas production, and more than 50% is exported (NAM, 2008). Most Dutch gas is sold by GasTerra, and transportation of gas is provided by the Gasunie. Natural gas provides for about one third of Dutch energy provision, mainly for heating homes and cooking, for electricity production and for industrial use.

The total energy consumption in the Netherlands increased from 2964 PJ in 1995 to 3348 PJ in 2007, an increase of 13%, or on average more than 1 % per year (CBS, 2008). Of this, 1351 PJ is oil, mainly for transportation, 1394 PJ is gas, mainly for heating buildings and electricity production, and 353 PJ is coal, mainly for electricity production.

Electricity consumption increased from 1980 till 2006 from 60 b kWh to 110 b kWh, an average yearly increase of 5%. Per household natural gas use was 1850 M3 (2005) and electricity use 3500 kWh (2005).

CO2 emissions from fossil fuels soared from 206 Mton CO2 in 1990 (Kyoto protocol; reference year) to 269 Mton CO2 in 2005 (EIA, 2008). This amounts to 8.7 ton per capita (UNDP, 2008). These figures are at first sight not consistent with the figures of the Dutch government (see section 2 below). The differences should be attributed to CDM and JI mechanisms.

2. Dutch environmental and climate policies

The Netherlands has earned the reputation of a frontrunner in environmental and climate government policies. After the Second World War, during the 'build-up' period, and through a period of massive industrialization, environmental problems like air, water, and soil pollution became significant. Especially in areas like Rijnmond, the harbor area west of Rotterdam, the industrial emissions created abysmal smog and smell; surface water

was so polluted that it threatened the quality of drinking water, while the level of ground water was falling; there were famous cases of soil pollution, not only in remote waste dumps, but also under residential new building projects. In the early 70s a new Government Ministry of Public Health and Environment was created, and environmental issues were mainly framed as 'environmental hygiene'. In this period the main policy instruments were strong direct regulation and inspection, and economic instruments like fees on pollutants and subsidies for end of pipe technologies.

In the 80s the Directorate-General of the Environment was transferred from the Ministry of Public Health to the Ministry of Housing and Spatial Planning; and a new Ministry was created (VROM), reflecting the new perceived linkage between building, spatial planning and the environment. Two major shifts in policy took place in those years: a shift towards a comprehensive environmental policy, away from 'compartmentalized' policies on air, water, and soil, towards for instance product policy, technology policy, extended producer responsibility, etc. The second shift was away from 'command and control' towards voluntary and negotiated agreements, especially with industry but also with other 'target groups'. In those agreements emission reduction targets were negotiated, but the ways these targets were reached was left to the target groups. Both shifts were consolidated in the first National Environmental Policy Plan (1989).

In the mean time the influence of the European Union on national environmental policies became more and more important, and the Netherlands played an important role in framing these European policies. A third shift took place in the 90s, when through the Program "Sustainable Technological Development" (STD), a five-departmental program led by VROM (Ministry of Housing, Spatial Planning, and the Environment), a long term perspective (50 years) was introduced in Dutch environmental and sustainability policy making. Through long term visions of sustainable housing, transportation, agriculture, and consumption, and through back-casting from these visions towards present actions, policies, and innovations, this program introduced a very different way of thinking about systemic changes necessary for reaching environmental sustainability (Vergragt et al., 1994; Weaver et al, 2000). These systemic changes were later framed as "transitions", and "transition management" became part of the Dutch national sustainability policy in the early 2000s (KSI Network 2008).

Energy policy was during all those years part of the Ministry of Economic Affairs (EZ), the Ministry that was most linked with Dutch business interests. EZ supervised the transition in the 60s from coal through oil to gas heating of houses, based on the enormous resources of natural gas discovered and exploited in the North of the Netherlands (Slochteren). In the same time, the Dutch government decided to close the last remaining coal mines in the south of Limburg, which created not only unemployment but also new industrial activity through the Dutch State Mines (now Royal DSM), which transformed itself from a coal mining company into a successful chemical bulk and specialties producer for the international market. In the 90s the international trend to deregulation, initiated by Reagan and Thatcher, also reached the Netherlands under the centre-right governments of prime minister Ruud Lubbers. Utilities became independent commercial business companies, and a wave of mergers followed resulting in presently five major utilities. Of these, three are domestic and two large ones are Belgian/French and German. The Dutch government and the local governments lost largely their control over investments and fuel

choice, with problematic consequences for investment decisions in sustainable energy, as we will see below.

Climate policy in the Netherlands became prominent after the ratification of the Kyoto Protocol of 1997. Before and after that, the Netherlands already played important roles in the creation of the UNFCC, the Kyoto Protocol, the IPCC, and other international sustainable development organizations. In 1999 a major Dutch policy document was issued (Uitvoeringsnota Klimaatbeleid) in which the policies were developed aiming at achieving the greenhouse gas emission reduction aims. Under the Kyoto Protocol, the Netherlands should reduce GHG emissions with 6% as compared to 1990; this could be partially implemented by Kyoto mechanisms as Joint Implementation and Clean Development Mechanism, and partially by domestic reductions, mainly through energy conservation and renewable energy. In an evaluation in 2005 it appeared that non-CO2 GHG emissions were reduced, but an increase in CO2 emissions compensated for that. A supplemental package of policy measures was announced to achieve the Kyoto reduction targets in 2008-2012 (Milieu en Natuurcompendium, 2008)..

Since the new centre-left government Balkenende IV was formed early 2007, climate policy and CO2 reduction have become even more prominent. For the first time CCS was explicitly mentioned in policy documents. As to the energy mix, decisions on new nuclear power plants were excluded during this government period, i.e. till 2011. However, quite recently nuclear energy is back in the political discussion, especially stimulated by the Christian-Democratic Appeal (CDA), a governmental party. The other governmental parties are against it. The CDA called upon utilities to come forward with proposals for new nuclear power plants (Volkskrant, 2008). These policies are endorsed by recent reports by the Energy Council and the Social-Economic Council, important advisory bodies for the government.

The cabinet reached, in its constituent accord, beyond Kyoto and towards 2020. It agreed to reduce CO2 emissions by 30% in 2020 as compared with 1990, from 215 Mton/y CO2 equivalent to 150 Mton/y; as compared to 246 Mton with unchanged policy in 2020; this would be a reduction of 65 Mton, or 94 Mton as compared to the extrapolated trend, and in accordance with the most ambitious version of EU reduction goals (-20% or -30% in case of an international agreement). The main reduction would come from industry and electricity production, from 101 Mton now till 75 in 2020, a reduction of 26 Mton CO2. In addition the contribution by renewable energy should be increased from 2% in 2007 to 20% in 2020, and energy conservation should increase from 1%/year now till 2% (VROM, 2008). The Minister of the Environment (VROM) became the coordinating Minister for Climate policy, and thus obtained a stronger position, at least on paper. Since the formation of the cabinet several important policy papers have been adopted or are presented for the implementation of those ambitious goals, the most important are “Schoon en Zuinig” (2007), the Energierapport (2008), and the Innovatieagenda (2008).

“Schoon en Zuinig” (“Clean and Frugal”) has been adopted by the parliament end of 2007. It is a ‘working program’ elaborating the short-term policies for the current 4-year cabinet period. As before, the main pillars of reaching Kyoto objectives and beyond remain energy conservation and renewable energy, but ‘clean fossil’ is now explicitly mentioned as one of the main options for CO2 reduction. The main instruments are voluntary agreements with target groups; after an evaluation in 2010 more stringent policy measures are possible. Other instruments are research policy, innovation policy, and transition

management for the long term systemic transition to sustainability. Many policies such as the European Trading Scheme (ETS) for CO2 emissions will be guided by or developed within the context of EU climate policies. As to CCS, the cabinet aims at two large-scale demo projects (out of the 12 proposed by the EU) in 2015 or earlier if possible. CCS should be 'market-conform', with the help of the ETS: CO2 emissions reduction should generate 'credits' and thus funding for the CCS investments. For the present cabinet period, 90 mln EU is available: 60 for two storage demos, and 30 for three capture projects (see sections 5 and 6 below).

The budget for "Schoon en Zuinig is roughly € 300 million/y for energy conservation, € 1 billion/y for renewable energy, € 150-250 million/y for innovation, and € 200 million/y international, a total of about € 1.5-1.9 billion/year.

The "Energy Report' appeared in mid-2008 and has recently been adopted by the Parliament. It addresses the question how to provide for a reliable, affordable, and clean energy provision for the short and the long term. It calls for a 'fundamental systemic change' in order to achieve a sustainable energy system. It takes an international perspective. Interestingly, it sketches three future visions without choosing one: The Netherlands as European power house, with a lot of coal and CCS; The Netherlands as 'energy flex working' with a lot of off-shore wind and natural gas; and The Netherlands as smart energy city, with a lot of local decentralized power, and a very smart grid.

Although the report's perspective is somewhat different than Clean and Frugal, it elaborates the same policy objectives and instruments. Interestingly, a direct coupling is made between the deployment of new coal power plants and the necessity for CCS. However, it also stresses the importance of gas as a "flexible backbone" of electricity provision. In this it follows the recommendations of the new "Regieorgaan Energie-transitie", a new independent advisory body that advises about long-term strategies and transitions. It further emphasizes the importance of off-shore and on-shore wind power. It sketches a vision of the "North Sea as a source of energy", including a 'gas-roundabout' (a metaphor), energy storage, and CCS. In this report a description is presented of the Dutch CCS project, which is being developed through the Task Force CCS.

A third policy document is the "Innovation Agenda Energy", which sums op which innovations are necessary and what government policies will help implement them. It is an elaboration of the innovation budget in "Clean and Frugal". It also mentions CCS under the theme "new gas".

In the assessment of the "Schoon en Zuinig" program by ECN (Energy Centre Netherlands), the Dutch ambitions are called ambitious and probably not achievable because too much is dependent on developments elsewhere in Europe and the developments of the CO2 price on the market (ECN, 2008). In the "low" EU scenario, with moderate EU policies and a modest CO2 prices of 20€/ton CO2, it is remarkable that there will be hardly a contribution by CCS is the Netherlands in 2020.

Although VROM (Environment) is now the coordinating Ministry, the role of other Ministries remains important. Especially EZ (Economic Affairs) still has an important voice in energy and climate policies, especially because they are now the centre of the Energy Transition Management. Apparently also the new program director for CCS was moved from VROM to EZ. Further the Ministry of Agriculture plays an important role in transforming agriculture towards a more sustainable form.

As a conclusion we can mention that CCS is a newcomer in the Dutch energy, environmental, and climate policies, as recent as 2007. Before that, it was not much more than a bottom-up research program (see section 5 below).

3. Regional CCS developments: Rotterdam and North Netherlands[2]

In The Netherlands two regions are emerging as the main players in the CCS implementation debate: the Port of Rotterdam (also called Rijnmond) and the North-Eastern provinces of Groningen, Drenthe, and Friesland (newly called "Energy Valley"). The latter is important for three reasons: a large potential on-shore storage capacity in smaller natural gas fields and eventually in the major Slochteren natural gas field; the presence of a harbor (Eemshaven) with industrial complexes and power plants; and the stated long-term wish for economic development of this somewhat remote and underdeveloped region.

The former is the Rotterdam port area, mainly west of the city of Rotterdam and including the "Maasvlakte", an area of land created in the North Sea for industrial purposes. It includes the largest harbor in Europe, together with petrochemical and chemical industries and power plants. In 2007 the Rotterdam Climate Initiative (RCI) was formed, under the chairmanship of former Prime Minister Ruud Lubbers, which is a collaboration between the City of Rotterdam, the Port of Rotterdam, the DCMR Environmental Protection Agency Rijnmond, and the industry organization Deltalinqs. This was greatly stimulated by a report of the City of Rotterdam's International Advisory Board, and subsequently by contacts with the Clinton Foundation. Rotterdam became an associate member of the C40, the Large Cities Climate Leadership Group, consisting of 40 large cities in the world who want to reduce their greenhouse gas emissions substantially; although Rotterdam is relatively small, its CO2 emissions are comparable to New York City because of its major industrial and harbor operations.

RCI's stated aim is the realization of 50% CO2 reduction in 2025 as compared to 1990, from 24 Mt tot 12 Mton, as compared to a projected 46 Mt in a trend extrapolation. This is considerably more than the national reduction goal of 30% in 2020. This reduction will be realized by energy saving (7 MT) and sustainable energy (7 Mt), but mainly through CCS in industry (20 Mt). This is of course an enormous challenge.

Apart from climate change arguments, the large CO2 emissions reduction aims are also justified by economic arguments: The Port of Rotterdam is highly dependent on fossil fuels (coal fired power plants and refineries), and wants to keep its leading position during the energy transition to sustainable energy; the geographical position of Rotterdam with a large concentration of CO2 emitters and nearby storage capacity, as well as the availability of residual heat, makes CCS less expensive as compared to other locationsand thus attractive for business; moreover Rotterdam could export technology and knowledge if it could develop as a frontrunner in deployment of CCS.

In a recent report by RCI and DCMR a plan is presented how to achieve 20 Mton CO2 reduction through CCS (RCI 2008). In the first phase, till 2015, a CCS capacity of 5 Mton CO2/year will be reached; in the second phase till 2020 this will grow to 15 Mton CO2/year, and finally 20 Mton CO2/year will be reached in 2025. The comparative advantages of Rijnmond are: availability of streams of highly concentrated CO2; an existing pipeline infrastructure that can serve as a start; a relatively short distance to both

onshore and offshore storage; a high concentration of energy-intensive industries; the availability of residual heat; and a favorable location compared to other high-CO2 emission areas like Antwerpen and the German Ruhr region.

Rijnmond has a large number of 'pure' CO2 point emissions in existing industrial installations, mainly from the production of hydrogen and biofuels. From these installations, and by post-combustion technologies, it would be comparatively less expensive to capture and compress CO2; this may amount to 2.9 Mt out of the total of 5.0 Mton CO2 in 2015. Post-combustion technologies are yet in the demonstration phase: recently a demo plant by TNO and E.On has been opened in Rijnmond. Post-combustion technology is still expensive (40 EU/ton); if the present technology based on amines could be replaced by ammonia technology this could be reduced to 13 €/ton. Also there is a lot of heat of good quality available in the Botlek area which could lower the costs by 4 €/ton CO2.

For the transportation of CO2 there is an existing pipeline that would have to be expanded to a network; for the first 5 Mton CO2 this would cost € 270 million; this would lead to transport costs of 20-22 €/ton.

Storage of CO2 for RCI is mainly foreseen offshore (estimated capacity 1144 Mton) and on-shore (1616 Mton). The best location is on the North Sea, and many smaller locations are foreseen on-shore. The on-shore location of Barendrecht (17 km from Shell-Pernis) is however considered crucial to acquire expertise in the management of CO2 storage, but is also considered crucial for the development of a regulatory framework. For CO2 storage on this location, a former natural gas field, requests for a permit and a subsidy have been submitted Shell, and this has already led to concerns by the local authorities and population (see section 7 below). The costs of storage are estimated 4.5-6.5 €/ton CO2. It is unknown if long-term costs of monitoring are included.

The total costs for capture, transport, and storage are thus calculated in the range of 25-57 €/ton, with the largest uncertainty in the capture. This is in the same range as the estimates by the European commission, which estimates that the price of emission rights from the ETS (the European CO2 Emission Trading Scheme) should be in the order of 39-45 €/ton in order to jumpstart CCS.

For the first phase until 2015 the investment costs are calculated as nearly € 300 million for infrastructure development and 400 million for demonstrating capture. In addition, the pre-investment costs for phase 2 (2015-2020), which should be made in phase 1, are estimated as about € 165 million. According to the RCI, both the national government and the EU will have to play important roles in financing these developments.

In 2007 the Mayor of Rotterdam signed an Intention Statement with the Minister of the Environment. In this, the Minister intends to create the necessary governance conditions for facilitation CCS, including inclusion of CCS in the European Trading System, and taking away regulatory barriers for implementation. No provisions have been made for extra financing by the Dutch government.

The developments in Energy Valley, in the North East of the Netherlands, are less elaborated and smaller in scale. In a speech, Max van den Berg, the governor of the Province of Groningen, stated on April 3, 2008 that the 4 Northern provinces and the central government have signed an accord in which they agreed to reduce CO2 emissions in the region by 4.5 Mton in 2011. He elaborated the strong position of the North with

respect to CCS: extensive storage capacity, a strong knowledge base, and the building of 4 new power plants, two of them just across the border in Germany, three of which are coal fired power plants. He proudly announced that RWE and Gasunie are collaborating in building a CCS demo in RWE's new powder coal power plant of 1600 MW, for € 100 M, to be finished in 2015, with a storage capacity of 0.1 Mton CO2 (Van den Berg, 2008). It is not clear if this would be one of the 10-12 large EU demos as proposed by the EU; it seems to be a high investment for a relatively low capacity of capture and storage (0,1 Mton as compared to 8.3-9.3 Mton CO2 emissions). It is also not clear how this investment capital will be raised and how much the government will contribute.

It appears that the regional initiatives, and especially the Rotterdam Climate Initiative, play a major role in stimulating the policy development on the national level. The regional initiatives are more 'hands-on', and the problems encountered there are fueling the national scene. The regional initiatives need national support by legislation and also through funding. There are strong, also personal, links between the Rotterdam Climate Initiative, the Energy Valley Initiative, and the national CCS Task Force. Also between the various regional initiatives there is a 'friendly competition' with a lot of mutual support.

4. CCS and new coal power plants[3]

A complication for the discussion on CCS are the discussions around the intended investments in new coal power plants in the Netherlands. End of 2007 no less than five coal power plants were planned in the Netherlands. Under a coal covenant of 2002 between the government and the electrical utilities, these plants should have the same CO2 and other emissions as compared to natural gas power plants (with an intended CO2 reduction of 3 Mton CO2 in 2012). The main mechanism to achieve less CO2 emissions is by mixing in biomass as feedstock. However, there is a maximum how much biomass can be mixed in, and biomass does not help to mitigate other emissions from burning or gasifying coal. Also it appears to be far from sure if the stored CO2 from this biomass can be counted in the mechanism of the ETS, so its benefits may not be counted in the European trading scheme. It is far from clear at this moment if the covenant is being implemented and what its present status is.

Three companies, the German RWE and E.On, and the Belgian/French company Electrabel, have concrete investment plans. RWE plans to build a 1600 MW power plant in the Eemshaven in 2011-2012, and Electrabel has two plans: one 800 MW in the Maasvlakte in 2012, and possibly one other 800 MW plant in the Eemshaven, also in 2012. E.On already started constructing its new 1070 MW coal power plant in the Maasvlakte. All these power plants will be built capture ready, although it is at this moment completely unknown what that actually means, except for making reservations for space.

Two other Dutch companies cancelled or postponed their plans. Essent has cancelled its plans, partially because of increasing costs, and partially because of public opposition, led by Greenpeace. Nuon, a major Dutch electricity utility who is building a 'multifuel' Magnum power plant (largely coal gasification) in the Eemshaven, has decided to postpone the building of their coal gasification unit; they are now building the natural gas power units. They claim that they will only build a coal power plant if the CO2 could be captured. For this they are experimenting in another coal gasification plant in Buggenum

with pre-combustion technology, which they develop themselves (subsidized by the government) and which is according to them very promising. They claim that the energy penalty for this pre-combustion capture is negligible, while for post-combustion capture it may be as high as 30%. According to Nuon their main driver is environmental stewardship.

Greenpeace is leading the public opposition against coal power plants. Their main argument is twofold: coal is a dirty technology over the entire chain, from mining to combustion, and alternatives (conservation and renewables) are available. The second argument is specifically about climate change: coal combustion emits more CO2 than any other fuel, and it seems to be counterproductive from a climate change perspective to switch towards coal. In the vision of Greenpeace CCS is used as the main argument to push for new coal power plants, and thus is used as a fig leave.

It is true that there are many questions and issues around these coal power plants, which relate directly to CCS. The first is, why to build so much new electricity capacity in the first place, in a period where the Dutch cabinet aims to achieve demand reduction by energy conservation, and aims to increase renewables form 2 tot 20 % in 2020? A recent report claims that the Netherlands may even change from an electricity importer to an electricity exporter (Seebregts et al, 2008). The main reason seems to be that large multinational utilities make their investment decisions on an European scale rather than on a country level; and The Netherlands have obvious comparative advantages (deep harbor access, availability of space, favorable government policies).

The second question is: why coal? Obviously coal power plants have lower direct investment costs than gas power plants or other alternatives. However, many studies have mentioned the high indirect costs, the high emissions, the accidents and environmental burden of coal mining, and others. Recent studies confirm that when the external costs (especially CO2 emissions) are included, natural gas has the lowest costs, while coal power plants have the highest (Sevenster et al, 2007). The societal costs of a 1000 MW coal power plant are calculated as 130 million €/year.

A study by SOMO, the research centre for multinational corporations in Amsterdam, commissioned by Greenpeace, gives a clear picture how profitable coal power plants are for the main electricity utilities in the Netherlands. (Wilde-Ramsing, 2007) All utilities show steeply increasing profits from 2002-2006, with increasing dividends for the shareholders. For the Dutch companies these are mainly provinces and municipalities. All companies had a high percentage of coal (and gas), and a very low percentage of renewables; some of the foreign companies also a high percentage of nuclear. RWE for instance generates electricity from 40% lignite, 27% coal, and 26 % nuclear, with 5% natural gas and 2% renewables. Their profits went up from € 1.7 billion to € 2.7 billion in three years. This suggests that profit making, and not climate change, is the main driving force behind the large investments in new coal power plants. That is not surprising after liberalization and privatization of power utilities.

A third question is: how do these coal power plants influence the level of CO2 emissions in the Netherlands? If all these power plants will be built, the effect will be a large increase in CO2 emissions rather than a decrease. According to Seebregts et al (2008) the E.On Maasvlakte will emit 5.3 Mton CO2, the Electrabel Maasvlakte 4.2 Mton, the RWE Eemshaven 9.3 Mton.

company	location	capacity	CO2 emissions	CO2 with

				biomass
E.On	Maasvlakte	1070 MW	6.2 Mton	5.3 Mton
Electrabel	Maasvlakte	800 MW	4.2 Mton	1.6 Mton
RWE	Eemshaven	1600 MW	9.3 Mton	8.3 Mton
Nuon	Eemshaven	1200-1400	6.1 Mton	3.0 Mton

Table 1: CO2 emissions from planned coal power plants

The Dutch cabinet states that the new coal power plants can only be built if they comply with the emissions standards; they also hope (but cannot enforce yet) that they will be capture ready. The Minister of the Environment was originally not very happy with these new coal power plants, and stated that she does not have the instruments to stop them if they comply with standards; this is a consequence of the deregulation and privatization of the 90s. Recently she changed her mind and defends coal power plants in combination with CCS as an argument not to build nuclear power plants.

It is hard to see how the building of new coal power capacity which will emit 20-26 Mton CO2 extra into the atmosphere will help to achieve the intended 60-65 Mton CO2 reduction in the Netherlands, even if these power plants would replace older and less efficient power plants. One argument is that the European Emission Trading scheme ETS (CO2) will take care of reaching the aim of -20% or -30% CO2 reduction in 2020, by means of the CO2 emissions cap. This may not be realistic: the effect of such a high cap might be such a spike in the CO2 price that it cannot be accommodated by the companies, and thus political pressure will grow to soften the cap.

It appears that the Dutch CO2 emissions from electricity generation have become subject to European policy rather than Dutch policy. Building new modern coal power plants in the Netherlands thus might enable to close down much more polluting old German lignite plants. It is strange that the ambitious and formally adopted Dutch climate policy plan nominally includes the emission of electricity power plants, which it cannot influence or reduce.

Next there are questions about the fuel mix of electricity production with respect to variability and peak use. In a scenario with such a large increase in coal power plants, there will be less room for the (also planned) 2 MW offshore wind. In order to balance the variability in such a large amount of wind power, a highly variable backup is necessary, which needs to be provided by gas turbines and other variable sources, and which cannot be provided by coal (or nuclear). Thus, the planned coal power plants may push the off-shore wind plans towards the sidelines.

Finally, CCS is used in the public debate to justify the coal power plants. CCS is mentioned in all investment plans as a technology that will mitigate the CO2 emissions. However, as we know it is far from sure that CCS will ever be available on a large scale, and what the time frame will be. Not mentioned is that in the most optimal case CCS will be not earlier than 2020 fully operational, while most coal power plants are planned for about 2012, with probably more to come between 2012-2020. This means that for many years the plants will emit CO2 without capture. Also not mentioned is that especially post-emission capture as intended by all except Nuon carries a huge energy penalty, meaning that 20-40% of the new power will go into capturing and storing CO2, while causing more other emissions.

5. The role of bottom-up CCS research in the Netherlands[4]

The emergence of CCS in the Netherlands was at first very slow, and recently surprisingly rapid. Back in the 90s of the previous century, there was just one person in the Ministry of the Environment (Mr. Jip Lenstra) who pleaded for CCS. For nearly everybody else, CCS was considered a "dirty end-of-pipe solution". The University of Utrecht had its first study and PhD dissertation around 1990, and in 1992 they organized the first international conference on CCS in Amsterdam. In 1998 the Utrecht University Centre for Energy Research was founded, with a program based on what they called the 'trias energetica': energy conservation, renewable energy, and 'clean fossil'. But as late as in 2003 money became available (from a competitive bid for 'research infrastructure funds' from Dutch natural gas remits) to finance CCS research on a somewhat larger scale, and in 2004 the 5-year CATO program (Dutch acronym for CCS) was launched with a budget of about € 25 million, about half of which was financed by the government. This thus was a truly bottom-up initiative led by academic scientists.

CATO consists of seven work packages: System Analysis and Transition, Capture of CO2, Storage of CO2, Mineralization, Monitoring, Safety and Regulations, Communications, and Management and knowledge transfer (CATO, 2008). It is novel in the sense that many different research groups from very different fields of expertise are working together on a common objective. Several of the work packages are specifically aimed at integration. Some issues that emerged were: criteria for sustainability of CCS systems; which of the many technological options are most promising or desirable; questions about storage potential, safety, and ecological risks, as well as the accessibility of storage sites for injection.

CATO is led by a consortium which includes major Dutch Universities, Shell Netherlands, other energy and gas companies, the Dutch government, Energy Centre Netherlands, TNO, and NGOs like Greenpeace Netherlands, Netherlands Foundation for Nature and Environment, and WWF (Netherlands). In the beginning the Dutch government was hardly interested, but that changed quite quickly. End 2005 a Working Group Clean Fossil was formed who reported very quickly, mid 2006 (Platform Nieuw Gas, 2006). By early 2007, the newly formed Dutch government Balkenende-4 endorsed the CCS policy including the intention to build 1-2 of the 12 European large demos in the Netherlands. The Ministry of Economic affairs also funded in 2007 three small scale CO2-capture demonstration projects with total project costs of 140 million Euro.

The CATO program quickly became seen internationally as *the* "National research program" on CCS of the Netherlands. However, it was not *designed* as a national research program, and was not equipped to advice the government on all issues that were raised, like accountability, liability, insurance, long-term governance of storage sites, and others. Thus soon after the favorable mid-term evaluation of the program a plea for a follow-up 'CATO-2' program was heard.

In 2007 the CATO program got a new chairman (Mr. Stan Dessens, a former Director-General Energy of the Ministry of Economic Affairs) who also chairs the new Task Force installed in 2008 by the government, thus strongly increasing both the profile of CATO and its interaction with the Task Force.

6. Latest developments and future of CCS in the Netherlands[5]

On April 3, 2008, the newly formed Task Force CCS was announced by the Dutch Minister of the Environment, on a national meeting of CCS. The occasion was the festive opening of a pilot CO2 capture plant by TNO and CATO, together with E.On. The CCS Task Force consists of important persons from Industry and Government, including a former Prime Minister, a Provincial Governor, the chairman of Shell Netherlands, a Director of Gasunie, and many others, including the director of the Netherlands Foundation for Nature and Environment (SenterNovem, 2008). Greenpeace, who did participate in the CATO project, chose not to be part of the Task Force.

Its main task is to create conditions for application of large-scale CCS in Rijnmond and North Netherlands. These conditions are: a market-ready technology, organization of the infrastructure, policy and juridical facilitation, financial arrangements, and societal endorsement. In four phases there will be till 2012 at least four capture and two storage projects; from 2012-2015 the building of two large demo projects; from 2015-2020 storage of CO2 in these large demo projects, and from 2020 large-scale industrial implementation of CO2 storage. In addition there will be CATO-2 for innovation and research in phase one; choices for storage sites, and the development of infrastructure in phase two; and financial arrangements for the short and the longer term. As to societal endorsement, the aim is a positive image of CCS. The political context is to help realize the policy objective of -30% CO2 emissions in 2020.

A crucial issue is the capture technology, which needs to be further developed and to become more cost-effective. Another crucial issue is societal acceptance, which is clearly identified by the Task Force as a major issue which is difficult to manage.

CATO-2 will be much larger than CATO-1, about € 100 million, and will be managed by TNO rather than by Utrecht University, to enable closer collaboration with industry. TNO itself has a strong knowledge base on soil technology.

Former Prime Minister Lubbers, now the chairman of the Climate Initiative Rotterdam and a member of the newly installed CCS Task Force, elaborated the plans both for CCS in Rotterdam and for the Netherlands (Lubbers, 2008). He presented the plans of the CCS Task Force, stressing two additional points: that The Netherlands have the best conditions in the world to realize CO2 capture, because of its knowledge base and the strong concentration of industries in Rijnmond; in addition there is the availability of residual heat which will be used for capture. He called for a thorough analysis of the on-shore and off-shore storage capacity. Even with the 'polluter pays principle' and the ETS system, 'transitional' government money will be needed to facilitate pilot projects, transport infrastructure, and storage investments. This is at odds with the position of the environmental movement as we will see below in section 7. The total investment for this will be € 270 million, to be co-financed by the government as co-investor or as contributor to transport and storage costs. In addition, 3-4 demo projects will be developed, each with an investment of € 100 million in the period 2009-2011; one third of the costs will have to be financed by the government.

In addition Mr. Jan van den Heuvel of the Rijnmond Environmental Authority sketched the plans to develop the Rotterdam Port area ("Rijnmond") into a major hub for CCS (Van den Heuvel, 2008). Around Rotterdam there is a high concentration of CO2 point sources, the proximity of storage sites both on-shore and off-shore, there is already an

existing CO2 infrastructure which might be in the future connected to the Antwerpen harbor in Belgium and the German Ruhrgebiet. In addition, local greenhouses could also be connected.

Also on April 3, Mr. Bert Stuij from SenterNovem, an energy development company liaised with the Ministry of Economic Affairs, elaborated the above mentioned plans for a 90 MEU impulse for three capture projects (30 MEU subsidy) and two storage projects (60 MEU subsidy) (Stuij, 2008). The subsidy funding comes from the "Borssele deal": a deal between the government and the operators of the only Dutch nuclear power plant to prolong the lifetime of that plant, and in exchange to fund GHG emission reduction projects. The first is a post-combustion cryogenic CO2 capture project at an existing E.On gas-fired combined heat and power (CHP) plant at the Maasvlakte, where 50% of the 'cold' is provided by a nearby LNG terminal. This technology would act as a pilot for the large-scale capture (2 Mton CO2) to be realized in the Eneco 850 MW gas-fired power plant to be built in the Maasvlakte in 2011.

The second is a precombustion capture unit at the Nuon combined IGCC-coal and biomass gasifier at Buggenum. This technology is a pilot for the intended multi-fuel power plant to be built by Nuon in the Eemshaven. The third is an oxyfuel plant which uses pure oxygen for combustion, to be realized in the North of the Netherlands.

The first two projects are going more or less as planned, with some delay; the first technology is key for adding CCS to existing power plants; the second is key for CCS in combination with the next generation Integrated Gasification Combine Cycle (IGCC) plants. The third project is another key technology with potential global significance, but still in the development stage with still many uncertainties.

7. Societal acceptance of CCS[6]

Societal acceptance of CCS is widely seen as crucial for its eventual implementation. The CCS task force sees it as one of its most important tasks. However, little has been done thus far to achieve this. CCS remains relatively unknown with the wider public, and is mainly known in policy circles, in the related business, and in some academic circles. This is remarkable because there might be wide societal resistance, ranging from 'NUMBY' (not *under* my backyard) to resistance to large-scale infrastructural works like CO2 pipelines, as well as resistance against the long-term liabilities.

Back in the 90s of the previous century, CCS was mainly considered a "dirty end-of-pipe solution". An important element to create a more positive attitude for CCS internationally and in the Netherlands has been the special IPCC report on CCS of 2005 (IPCC, 2005). In this report CCS was presented as a viable mitigation option for CO2 emissions.

Dr. Leo Meyer, the head of the Technical Support Unit of IPCC Working Group 3, who played an important role in the production of the IPCC CCS report, states in a personal capacity that he warns against too much optimism about CCS: no large-scale electricity production project world-wide has been implemented yet, a few projects have been cancelled; CCS is 'sold' as a bridge technology but that is a dubious argument, and a societal controversy like nuclear energy is very well thinkable. This is a remarkable position for somebody who has played an important role in producing the IPCC CCS report

which, although it was a scientifically 'neutral' report, was instrumental in making CCS acceptable to skeptical countries. We will return to his arguments below in section 8.

Societal acceptance has been recognized by the CCS Task Force as a crucial issue for the successful implementation of CCS. Other conditions for success are economic viability, enabled by integration of CCS in the European Carbon Trading Scheme (ETS) by 2012, and lowering of capture costs and energy use by technological innovations.

A study by the Utrecht University Copernicus Institute, also part of the CATO program, investigated the conditions for implementation of CCS technologies Van Alphen et al, 2007). This study focuses on the stakeholders in CCS who, as they claim, have a double influence on the development of CCS technology: a professional and an indirect, by helping to shape public opinion. The main conditions for implementation emerging from this study are safety, temporality and partiality, costs, simplicity, and cooperation and commitment.

Research by Dutch researchers from the Technical University Eindhoven links social acceptance of a new technology strongly to trust in the actors (Huijts et al, 2007). They did a survey (2003) in two cities that are potential storage sites. CCS was largely unknown. The attitude was slightly positive in general, but as to storage under the own residential area slightly negative. Trust in industry was lowest, in NGOs highest, and government in-between. Emotions included worries, powerlessness, and annoyance, not stress. Citizens seem to rely on feelings related to the technology, and trust in the actors. More information could help to stabilize opinions, but different research shows different outcomes: in Japan more information lead to more support for CCS, and American researchers reported more opposition. The conclusion is that it is not definitive if people will accept CCS in the end.

Research within the CATO program by the University of Leiden has confirmed that trust in institutions is more important than information or participation in decision making (De Best-Waldhober et al, 2006). As was already known, people trust environmental organizations more than business, and trust in the government is lowest. For information to be credible it should thus come from NGOs and not from government. Thus it is crucial for the success of CCS that environmental organizations endorse it; conversely criticism by NGOs could easily upset public trust.

From this research it appeared that 70% of the population had not heard about CCS; their opinion thus should be considered a pseudo-opinion because it could quickly change through new information. The researchers claim that people do not understand the causal chain of electricity production by coal power plants causing CO2 emissions, which causes global warming. If people are informed on all aspects of the technology, there is a lukewarm endorsement of about 60-65%; however this is not yet measured in the context of other mitigation options like conservation or renewables.

The Rathenau Institute, an independent institute that advises the Dutch Parliament on technological innovations and potential controversies, conducted a study on public attitudes by means of four focus groups. First outcome was that the connection between CO2 emissions and climate change was very blurred; some saw CCS as waste dumping while others considered it throwing away a valuable commodity. After providing information by an expert and by a protagonist and an opponent, three out of four groups were still divided; and only one group supported CCS. Participants were baffled by the high energy penalty (25%) of CCS. They state that CCS could be a transitional technology

but only for a very short time. There is anxiety about safety aspects and about long-term management of storage sites. There is distrust towards the initiators. NIMBY is a sensitive issue.

The author conducted his own focus group study in April 2008 with an ecoteam of which he is a member[7]. This ecoteam was formed in 2000 and convenes irregularly. It is a neighborhood group; all its members are environmentalists and very motivated to reduce energy consumption in their own households; so this was *not* a representative sample of the population. Surprisingly, in this group of six highly educated and environmentally motivated people, three had never heard of CCS at the beginning of the evening. Before any information was given, two out of these three were undecided, and one was in favor of CCS; of the other three participants, one was against (and informed) and the other two were favorably inclined. After providing information most people were surprised about the scale and speed of these developments. At the end of the evening, one of the previously uninformed persons, who was in favor at the beginning of the evening, was now against CCS, illustrating the unstable character of opinions of uninformed people. The two somewhat informed and favorably inclined changed their position towards more skeptical. Two persons maintained that this was "too technical" for them to form an opinion, and the informed adversary remained against.

The problems with public acceptance surfaced around the CCS storage project in Barendrecht. Shell applied for a € 30 million subsidy for injection and storage of very pure CO2 from its Pernis oil refineries. The population is not happy with storage "under their backyard", and the local political parties are very cautious. DCMR and EZ will issue a permit after a safety and environmental assessment, and VROM needs to decide on a subsidy; both have been postponed. The Rotterdam Climate Initiative sees this project as crucial for its roadmap to develop CCS in the Rotterdam harbor (NRC, 2008). Apparently the decision to start a first CO2 storage project under a residential neighborhood was made by the Rotterdam Climate Initiative very consciously, weighting the factors pro (communicating confidence in safety of storage) and con (risk of public resistance). In the opinion of this author it does not seem to be a very good idea, given the research cited above, to start the first CCS project above a residential location, even if it is proven to be safe. Clearly an overarching communication strategy is missing.

The big environmental NGOs in the Netherlands have different positions on CCS. The Foundation for Nature and Environment (SNM) is cautiously in favor ('yes, if"); they are also part of the CCS Task Force. Greenpeace Netherlands and GP International however moved recently from "no, except" towards "no, because". Greenpeace sees CCS very much in the context of Dutch coal policy. In 2002 the Dutch government negotiated a coal covenant with industry. In return, a tax on coal was already banned in 2002. Greenpeace would like to condition the permits for new coal power plants to the implementation of CCS, like in Alberta, Canada, but in the Dutch political context it seems to be impossible to condition a permit on the availability of a not-yet proven technology[8]. In constrast, former Prime Minister Lubbers states that the government indeed has a large influence on the investment decisions of companies; as an example he mentions the (near absence) of nuclear power plants in The Netherlands; thus the Dutch government would be able to object to new coal power plants if it wanted to do so[9].

8. Reflections: Speed of development and carbon lock-in

In this section we reflect on two major questions. The first is how we can explain that CCS has been emerging so fast as a major technological and policy tool for CO2 reduction, as compared to other options like energy conservation and renewables. The second is the question if large-scale CCS would lead to a continuation and a reinforcement of the fossil fuel lock-in, which could be held responsible for the slow emergence of sustainable energy sources.

CCS has moved from a rather obscure technology option and research object to a major policy option as recently as 2007. In contrast, wind, solar PV, and other renewables have been around as technological and policy options for decades, but never really took off. There are many reasons to explain the latter, ranging from high research and investment costs, to resistance by the population (wind turbines!) and lack of interest by the public and by the actors in for instance the housing industry. But a major reason seems to be that no big business interests have pushing for solar PV and wind. Sure enough, electricity utilities have invested in renewables but the percentages are low. Another argument could be a complacency fueled by a large availability and use of natural gas for residential heating, and its relatively low carbon content as compared to oil and coal. But sure enough, neither government nor business has been pushing very hard for renewables.

In contrast, the emergence of CCS seems to be driven by three major factors. First there is the growing awareness of climate change, and the broad realization (contested by Greenpeace) that renewables and conservation are too slow and too costly to mitigate CO2 emissions in due time. Second is the interest of the major electricity utilities in CCS, which they see as a major opportunity to enable them to invest in cheap coal rather than in expensive gas power plants. Third is the influence of regional lobbies like the Rotterdam Climate Initiative, which combine the wish to be a frontrunner in CO2 reduction with the opportunity to position the regions as more favorable for energy-intensive investments, because of the closeness of CO2 storage capacity and, in the case of Rotterdam, the lower costs because of the availability of residual heat. These three factors push the drive for CCS.

However, it is far from sure that CCS will succeed as envisioned. The high costs and the high energy penalty, as well as the absence of a regulatory framework make it rather questionable that it will roll out as fast as envisaged by its proponents. The main obstacle it this moment seems to be funding. There is a lot of pressure on the government to finance large parts of capture research, big demo projects, and infrastructure, either directly or through ETS. In the Dutch multiyear budgets there are no big provisions for funding CCS projects. Recently (December 2008) the EU Council decided under pressure from the European Parliament to allocate EUR 6-7 billion from ETS to fund the planned large demos. This of course is contrary to the earlier developed idea that each country was expected to pay for its own demos, and also against the proposed market mechanism. A necessary condition for continued funding would be a stable and high (€ 45) CO2 price. There are rumors that the European Investment Bank (EIB) would be willing to guarantee a minimum price in exchange for stringent EU policies on CO2 reduction (i.e. lowering the number of certificates significantly).

A second caution is public opinion. At present the public knows very little about CCS, and it is not easy to change that. The relatively small-scale storage of CO2 under a

residential area in Barendrecht, and its creation of a lot of concern with population and local politicians, brought the issue to public attention in a negative way. If public opinion would turn against CCS, which might very well happen in the not too distant future, the proponents have a problem. An unlikely coalition has already been formed between the (green) opponents of CCS and the right-wing proponents of nuclear energy: both assume (probably rightly so) that if CCS is delayed, nuclear energy will get a better chance.

As to the second question, about CO2 lock-in, it is clear that CCS is driven by main business actors who have a vested interest in the fossil fuel industry, especially in coal, less so in oil. A complete transition to conservation and renewables as envisaged by Greenpeace does not have a lot of support from those business interests. Utilities have been marginally investing in solar and wind, and somewhat more in biomass, but it is not much more than fringe. The presence of a large amount of natural gas has further given rise to some complacency about space heating, because gas has relatively low CO2 emissions. Oil companies like Shell also have been slow in investing in renewables, in contrast to their public relations messages. Each of those companies sees CCS as an opportunity to continue business as usual, while mitigating CO2 through storage, and financed by the ETS.

One could call this a continued lock-in of fossil fuels, especially of coal; by means of the power of fossil fuel industries, the interests of the Rotterdam harbor and other main players, the economic interests of the Netherlands in oil and gas, and the possible revenues coming from new business opportunities, CCS is now seen as possibly a lucrative investment. CCS does many things: it 'buys time' before the necessary switch to renewables and conservation; for some it delays nuclear energy; it brings to the table powerful actors, and last but not least it facilitates coal power plants, the most pollutant form of electricity generation.

The concepts "lock-in" and "path-dependency" have been developed by Brian Arthur and Paul David to describe how technologies and socio-technical systems could eventual become suboptimal solutions for new societal challenges, because of the vested institutional interests and the sunk costs of investments in infrastructure and knowledge (Arthur, 1985, 1989; David, 1985). Gregory Unruh has applied this concept to carbon-intensive technologies; he calls it the techno-institutional complex (Unruh, 2000). He calls for a new techno-institutional complex to address the current climate crisis (Unruh, 2002).

Fossil fuel lock-in would mean that it would become eventually even more difficult to move away from fossil fuels to renewables and conservation. And indeed, it is hard to see how investments of billions of Euros in capture, infrastructure for transportation, storage, monitoring, and safeguarding will not be used in the future as an argument to continue CCS rather than move to renewables. All institutions which now invest in CCS, either monetary or by creating regimes for regulation and monitoring, will have vested interests to continue this system to remain functioning in the far future. Even in the best case scenario, when investments in CCS would only be made in the period 2020-2040, coal would be used on a massive scale till at least 2080 (assuming a 40 year deprecation time) Beyond that date monitoring and safeguarding of CO2 storage will remain necessary for an unforeseeable time, even if business and politics would move away from CCS between 2040-2080. The 'bridge' technology would require a very long bridge indeed! This would not so much be a problem if CCS would not be costly, energy-intensive, and in essence an

end-of pipe solution with few collateral benefits next to greenhouse gases abatement; and if storage capacity would be unlimited, which it is not.

9. Conclusions

The development of CCS in the Netherlands is apparently not very different from other countries in the EU and the USA. Until just a few years ago, CCS was not taken very seriously in policy circles and in research institutions. Of course, oil companies have a long history of using CO2 injection in the soil for oil and gas recovery. Similarly, CCS is very much in line with their usual operations, which are large-scale and centralized, and thus do not constitute a threat to their business models. On the contrary, it appears that CCS creates new economic and business opportunities for the incumbent oil, gas, and coal industries.

In a very brief period, under the influence of the climate debate and the EU and Dutch CO2 reduction policies, CCS has become an important issue in the Dutch climate policy. This happened also under the influence of the CATO research program, which quickly became seen as *the* Dutch national research program on CCS. Because of its governance structure, which included not only the protagonists but also strong environmental NGOs, a powerful network quickly developed on which the government could build its CCS Task Force for implementation of the next steps. Notwithstanding this optimism there is also caution, because CCS is costly, energy intensive, and needs to be carefully developed and implemented. A necessary condition is that CCS will become part of the ETS carbon trading system in 2012, with a stable (and possibly guaranteed) price for CO2 of about EU 45 on the market. The Dutch policy on CCS is quickly becoming part of EU policy, which coordinates 12 large-scale demo projects; the Dutch want at least 1-2 of these demos to be built in the Netherlands around 2015.

Nearly all interviewees stated that public endorsement is a crucial prerequisite for the success of CCS; most of them were cautiously optimistic, but much needs to be done in the form of information dissemination and communication. The environmental movement is divided, with Greenpeace recently moving to an “against, because” position. It is not probable, but also not unthinkable, that public opinion may turn against CCS, especially if the public is not well-informed and if some accident might happen. Already a first experiment of CO2 injection under the soil of the town of Barendrecht led to resistance among inhabitants and rather negative press reports in the newspapers.

Concluding we state that CCS is a large-scale infrastructural technology jointly driven by climate change policies and economic motives, which cannot be decoupled from the larger energy provision system, especially coal and nuclear energy. In a deregulated world it is much harder for the national government to orchestrate developments; business, NGOs, the regional initiatives, and the public have become main stakeholders in this process. However, national government funding and regulations, and European Union policies (ETS!) are crucial for take-off; while public acceptance might easily become a major bottleneck. According to former Prime Minster Mr. Ruud Lubbers, “the glass is thus half-empty or half full”[10]. Ultimately the question needs to be answered if CCS is a sustainable option or just another technical fix which does not solve the underlying challenge of unsustainable development.

Endnotes:

[1] This chapter is based on literature study and on interviews with eleven main players in the Dutch CCS: the coordinator of the Research Network CATO; the secretary of the Energy Transition; the co-author of the IPCC report on CCS; a researcher on public acceptance; Greenpeace Netherlands; the Chairman of the CCS Task Force; a head of department of Senter-Novem, the Dutch energy agency; the director of Alstom Power, a director of Nuon utility company, the director of the Environment Protection Agency Rijnmond Rotterdam, and a former prime minister and chairman of the Rotterdam Climate Initiative. In addition, I conducted a focus group discussion with the Ecoteam Adegeest in Voorschoten, and I used the results of a focus group research project by the Rathenau Institute. The opinions and interpretations are entirely my own. I wish to thank the interviewees for their time and interest.

[2] This section benefited from the interview with Mr. Ruud Lubbers of RCI, and Mr. Van den Heuvel of DCMR; the latter part also from the interview with Mr. Robert de Kler of Nuon

[3] This section benefited from two discussions with Hans Altevogt, Greenpeace, and the interview with Mr. De Kler, Nuon.

[4] This section is mainly based on the interviews with Mr. Eric Lysen and Mr. Sander van Egmond of CATO.

[5] This section benefited from an interview with Mr. Stan Dessens.

[6] This section benefited from the interviews with Dr. Leo Meyer of MNP and IPCC, Mr. Dancker Daamen of Leiden University and CATO project, the Rathenau Institute, Mr. Hans Altevogt of Greenpeace, and Mr. Ruud Lubbers of the RCI..

[7] Ecoteam Adegeest Voorschoten; contact the author

[8] Mr. Hans Altevogt, Greenpeace, personal communication April 9, 2008.

[9] Mr. Ruud Lubbers, interview, Sept 16, 2008.

[10] Mr. Ruud Lubbers, interview, Sept 16, 2008.

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