

Chapter 1

Status Quo and the Aims of the Study

Long-term scenarios on the development of energy systems show that the transition to a climate-friendly energy supply will in some way rule out coal. However, coal is the fossil fuel with the largest global reserves – distributed over many regions of the world – and is subject to fewer geopolitical risks than oil and gas.

This raises the question of how the use of coal could be made more climate-friendly. Alongside improvements in the efficiency of the various ways coal is used (primarily by increasing the conversion efficiency of power stations and expanding the use of combined heat and power) the technology option of carbon capture and storage (CCS) could also make a contribution. Its introduction could make it possible to produce ‘low-CO₂’ energy based on coal. The important fields in this context are electricity generation, and even more so the production of hydrogen as a universal storable fuel. The same also applies in principle to natural gas and oil, although from the climate perspective natural gas is a less critical issue owing to its lower carbon intensity.

There are still many unanswered questions today concerning the possibilities of capturing CO₂ and especially storing it safely for a very long time. These questions include not only how much safe, long-term storage capacity there actually is for CO₂ (and its regional distribution), but also what costs and ecological risks are involved. If CCS can be successfully introduced as a new technology option at reasonable cost and with acceptable ecological impacts, it could make a major contribution to providing a more secure and climate-friendly supply of energy.

Previous studies in this field have tended to concentrate on the general technical feasibility of the concept. There has not yet been a detailed examination of the ecological, economic and social impacts along the whole process chain (e.g. energy balance, cumulative energy demand, environmental impact, use of resources, risks, costs) of the kind that is a matter of course today for other new technologies, especially renewables. Only after such scrutiny will it be possible to decide how environmentally beneficial this technology option really is, what advantages and disadvantages it has compared with renewables and what contribution it can make to a sustainable economic structure. That is the focus of the present study.

This project is particularly relevant in view of recent political initiatives on international level for using the so-called ‘clean coal’ option, extensive research activities globally and the publication of the German Environ-

ment Agency’s assessment of CCS from the sustainability perspective in mid-2006.

More and more scientists, politicians, and NGOs are calling for investigation and consideration of ‘clean coal’ technology. The energy sector itself is planning to open various small CCS demonstration plants in 2008 and the following years mainly in Europe and USA.

The findings so far show that introducing carbon capture and storage only makes sense if done on a large scale. Given the great volume of investment required and the implications for other options for reducing greenhouse gases, the decision about whether CCS should be made a central pillar of energy policy will have to be thoroughly considered on a solid scientific basis. It is already recognised today that new technologies will have to satisfy numerous technological, structural, economic, ecological and social criteria before they can be regarded as viable options for a sustainable future energy supply. So they will be subjected to a rigorous selection process before their suitability as future key technologies is accepted. As well as detailed investigation of the potential, the achievable future costs, the implications for industrial policy and social impact of a technology, differentiated life cycle assessments (LCAs) of the whole system represent a suitable instrument for assessing the practicability of new technologies against various sustainability criteria. Very detailed LCAs are already available for the various technologies based on renewables, which represent one of the main other options for avoiding greenhouse gases. Suitable data for making a solid assessment of capability and environmental and system impact are also already available for numerous technologies in the field of efficiency (e.g. modern combined heat and power).

The goal of this project is consequently to weigh up the range of technologies for carbon capture and storage currently under discussion in terms of their fundamental suitability for a future energy supply. We outline several reference systems and realistic system configurations for supplying electricity and hydrogen together with all the relevant data required to properly appraise and assess the options in the scope of an overall concept for a future sustainable energy supply. These make it possible to identify the fundamental potential of the proposed technologies, the technological advancements still required and the environmental impact. A systematic comparison with other options for a climate-friendly energy supply – especially the use of renew-

ables – concludes the study. This is the context in which the discussion about the possible role of the CCS option in longer-term energy supply scenarios must be conducted, in which the timeframe of future development steps (establishing an infrastructure) must be considered and in which fundamental energy policy decisions must be addressed. This investigation supplies a sophisticated set of data for placing the carbon capture and storage option in the energy and especially the climate policy context. As such it can make an important contribution to energy policy decisions currently on the agenda.

The principle research questions can be summarised as follows:

- What are the conceivable routes for CCS (technologies, infrastructures, development timetables)?
- What does the overall life cycle assessment of these processes look like, and how does low-CO₂ fossil-based electricity compare with CO₂-free options, especially renewables (comparison on an equal footing)?
- What role can CCS play for climate protection in comparison with other relevant options, and when (systematic comparison on the basis of significant criteria such as cost, timeframe, ecological restrictions, etc.)?
- What role can CCS play as a possible bridge to a renewable energy system?

The report has **five parts**:

Part one (introduction and background) examines the driving forces behind CCS and the attitudes of relevant actors.

Part two takes a closer look at technological developments in the field of CO₂ capture (in electricity generation and hydrogen production) and at the individual steps involved in CO₂ capture, transport and storage.

The **third part** presents a comparative assessment of CCS and other relevant climate protection technologies on the basis of a comprehensive set of criteria. The life cycle assessment method (LCA) is used to conduct a thorough comparison of the ecological performance of CCS in comparison with continued expansion of renewables. The economic parameters are also examined in greater depth. Additional criteria are used to differentiate and expand the comparison with renewables.

Part four examines the significance of CCS for national energy sectors, including thorough system and scenario analyses. The significance of CCS and renewables for energy and climate policy are compared. The Germany energy system was chosen as an example.

Finally, **part five** turns to a more global perspective on CCS, showing the requirements and preconditions that have to be met for international implementation of this technology option.

Chapter 2

Terminology

Before proceeding to the body of the report, it would seem appropriate to examine the definitions of the fundamental concepts involved in carbon capture and storage.

In the literature on ‘carbon capture and storage’ we find divergent terminology being used.¹ The issue itself is often subsumed under the term ‘low-emission/carbon-free (coal) power stations’ or the catchword ‘clean coal.’² The following table presents a selection of the terms commonly found in the literature. The first column lists the umbrella terms for the whole process from CO₂ separation through conversion and transport to storage, while the second and third columns respectively list synonyms for the individual processes of CO₂ capture and CO₂ storage.

Table 2-1: Terms relating to carbon capture and storage

Carbon capture and storage (CCS)	CO ₂ capture	CO ₂ Storage
CO ₂ sequestration	Separation	Disposal
Carbon management		Discharge
		Injection
		Insertion
		Dumping
		Removal

It should be noted that the terms are applied with varying precision. For example ‘storage’ strictly speaking means to ‘keep for the purpose of later retrieval.’ This applies to the CO₂ issue only if ‘storage’ is indeed intended as a temporary solution (which, depending on the storage technology and the order of magnitude of the associated leakage rate, it may well be).

Certain of the terms listed in the ‘CO₂ storage’ column relate only to particular sinks. For example, ‘dumping’ refers to storing CO₂ in the sea.

It should also be noted that some of the terms are positively or negatively loaded. For example, the term ‘storage’ sounds rather positive, ‘insertion’ is more neutral, while the term ‘dumping’ may have more negative connotations, in particular due to its association with the controversy over dumping of radioactive waste at sea. Richter (2003) uses this phenomenon to classify the users of the different terms into supporters and opponents of ‘CO₂ sequestration’.

In this report we primarily use the terms set in bold in the above table: ‘carbon capture and storage’ (‘CCS’), ‘capture’ and ‘storage’.

1 ‘Sequestration’, for example, is normally taken to mean the whole process from separation through transport to storage. However, some authors use the term to refer only to CO₂ separation at the power station, while others use it exclusively to designate storage, for example in a geological formation.

2 The terms ‘emission-free’, ‘CO₂-free’ and ‘clean’ are misleading, because with today’s technology it is only possible to reduce CO₂ at the power station by about 80 to max. 95 % compared with conventional power stations. Additionally, depending on the technology, other pollutants (SO₂, NO_x, dust, etc.) may still be emitted (indeed, owing to the increased energy requirement possibly even in increased quantities).

Chapter 3

Driving Forces: The Attitudes of Relevant Groups to CO₂ Capture and Storage

The development of technologies for the capture, transport and storage of CO₂ is being promoted from various actors and driving forces. These include:

Global driving forces for climate protection: The necessity of reducing emissions of greenhouse gases, in particular CO₂, has given a clear boost to CCS at the global level. This applies especially to those who doubt that long-term climate protection goals can be achieved at all or achieved quickly enough solely by expanding sources of renewable energy and significantly improving energy efficiency. In their view, as long as it gains sufficient acceptance by various actors, including the consumer, CCS could provide considerably more leeway for action and reduce the pressure for developing renewable energy and energy efficiency. For this reason some actors speak of CCS having a ‘joker function’. Its advocates even include some states that have tended in the past to take a negative attitude to the international climate protection process. Here the United States in particular should be mentioned as a major promoter of CCS. A roadmap produced by the US Department of the Environment (DoE) envisages the first pilot and demonstration facilities being completed in 2018 (DoE 2003). In the few climate protection scenarios produced by the United States CCS is assigned a dominant role. Experts at the DoE believe that stabilising emissions at

the present level will only be possible if the overwhelming share of emissions reductions is achieved via CO₂ capture and storage (Fig. 3-1).

This ‘enthusiasm’ can be explained by the fear in the United States that the increased use of renewables and an increase in energy efficiency will place an unacceptable burden on the economy and will excessively limit the ‘freedom’ to use energy. In addition the strong lobbies of the oil and coal industries play a significant role in shaping US government policy on this issue. The United States has also made advancing CCS a major task of the Asia-Pacific Partnership.

But in other countries, too, CCS enjoys a strong measure of support in the context of climate protection. Examples include Japan, the Netherlands and Germany. In Germany, Vattenfall Europe has become the first energy supply company to begin building a low-CO₂ oxyfuel-based demonstration power station (30 MWth in the first phase of the project), and the Federal Ministry of Economics and Technology has launched a major research and development program in this field called COORETEC.

National energy security: The obligation to protect the climate in some respects clashes with requirements for

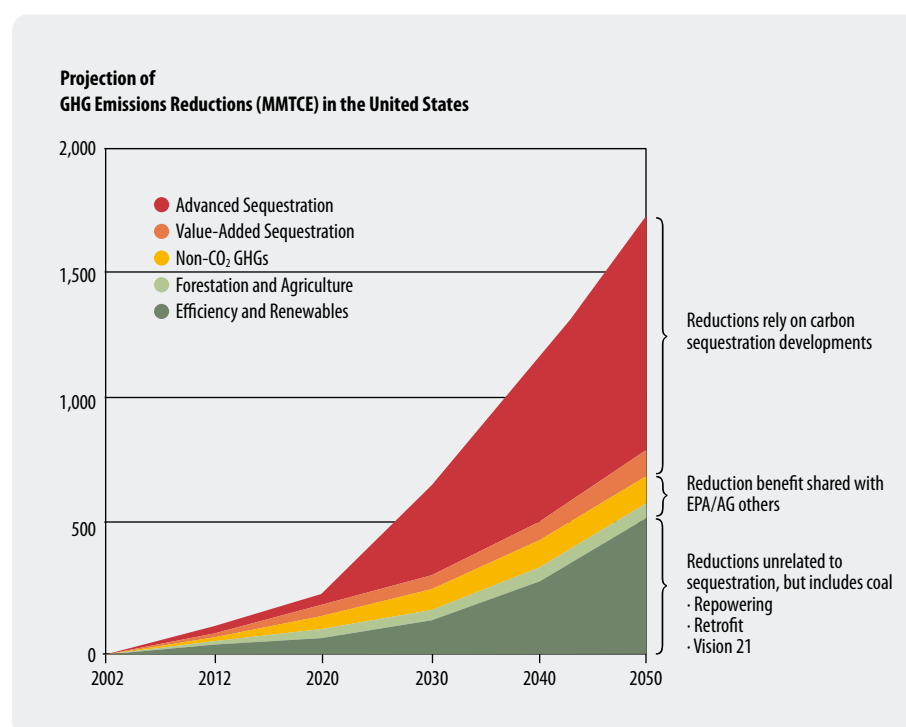


Fig. 3-1: Emissions reduction requirements compared with the trend in stabilising CO₂ emissions in the United States (DoE 2003)

states and communities of states to maintain or improve their energy security (see the European Union green papers on Security of Supply and Energy Security [EU 2006, 2001]). For many countries a baseline contribution from fossil fuels (mainly coal) is essential, since they have their own reserves of these. In order to attain climate protection goals nonetheless, the argument goes, it is imperative to engage in CO₂ capture and storage while maintaining or even increasing the proportion of fossil fuels.

Many states, particularly India and China, are currently experiencing strong economic growth. In order to maintain their energy supply they believe it is essential to increase exploitation of domestic coal reserves, since other sources of energy cannot be tapped as easily, as quickly or as cheaply. Even if these countries have yet to enter into any quantitative climate protection obligations, the protection of the global climate plays an increasingly important role for them.

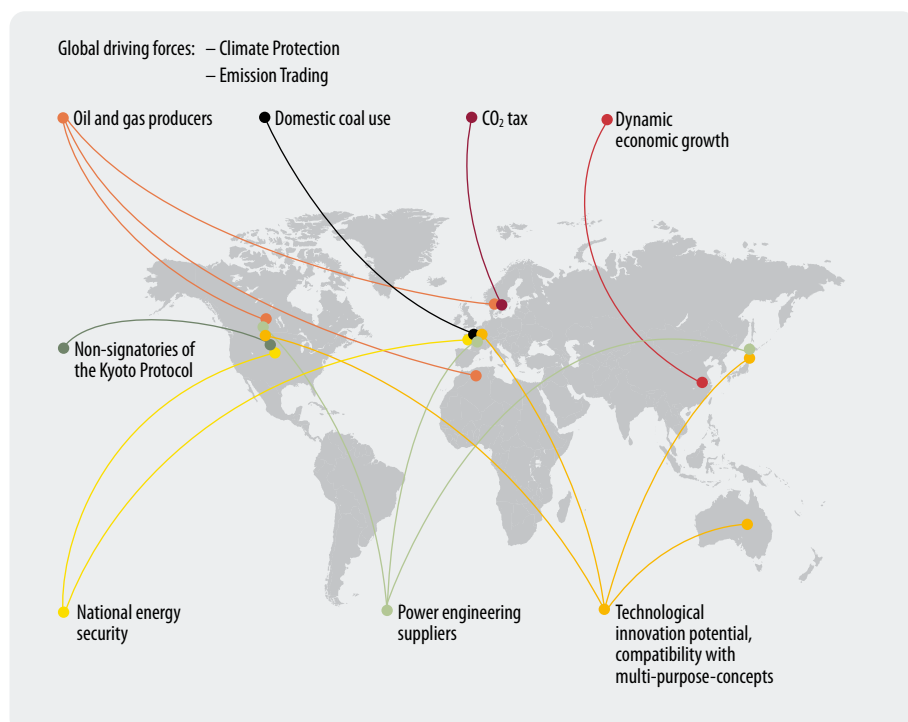
Technological innovation and export opportunities: Technological advancements have facilitated some aspects of capturing CO₂ in the power station process. This applies, for example, to coal-fired power stations with integrated coal gasification (integrated gasification combined cycle: IGCC), where the CO₂ produced during gasification can be separated from the resulting synthesis gas fairly easily prior to the combustion process. Subsequent storage of the CO₂ is then seen as a logical extension of the process for the purpose of climate protection. Here capturing CO₂ is seen not as the direct purpose of the new process – as it is for example when sulphur dioxide or nitrogen oxide is separated during flue gas cleaning – but rather as a side-effect.

Another, comparable issue is compatibility with a coal-based hydrogen economy (polygeneration of electricity, heat, synthesis gases and hydrogen). There is currently a fair degree of optimism about the future use of hydrogen as a fuel. Coal gasification represents one possibility for production of H₂. The rise in the prices of oil and gas is causing this approach to receive an increasing amount of attention. The same applies to the process of liquefying coal to provide fuel, known as coal-to-liquid (CTL). To make these processes compatible with protecting the climate, safe storage of the by-product CO₂ is necessary.

Plant engineering: Many power engineering businesses and component suppliers see the large-scale introduction of CO₂ capture processes as providing major economic opportunities not only to sell the additional components required to build new fossil-fuelled power stations but also generally to preserve the market for large-scale power stations. The large proportion of high-tech components required for coal power station processes involving CO₂ capture also means that exports of these technologies achieve correspondingly high added value. The building of a transport infrastructure for CO₂ would also open up new areas of business for suppliers in the pipeline construction sector.

Economic incentives: Several states such as Denmark and Norway have introduced a CO₂ tax. The economic incentives that this tax provides for avoiding CO₂ emissions were the main reason why the Norwegian oil company Statoil decided to launch what is to date the world's largest CO₂ storage project and to store in a geological formation approx. 1 million tonnes of CO₂ produced

Fig. 3-2:
Factors promoting CO₂
capture and storage world-
wide



annually as an undesirable by-product in the extraction of natural gas from the Sleipner gas field (Statoil 2004). Oil companies also have an increasing interest in CO₂ capture, since in the process of enhanced oil recovery (EOR) CO₂ can increase the yield of oil extraction.

The various factors can be assigned differing degrees of importance depending on the region. The above diagram (Fig. 3-2) gives a broad overview of the major factors in various regions of the world.

3.1 International and German NGOs

Where non-governmental organisations (NGOs) are concerned, the process of developing positions on CCS has turned out to be very diverse and complex. Overall, NGOs (including those outside Europe) concur on only three points:

- They reject the storage of CO₂ in ecosystems – specifically oceans,
- Currently (February 2008) no campaigns against CO₂ disposal are planned,
- Renewable energy and more rational use of energy should be given priority over CO₂ storage and their implementation should be pushed.

There is no common position that goes beyond these three points. One major reason for this is that the positions of the national NGOs must always take into account the national energy situation (expected energy consumption trends, fuel mix, domestic energy resources, etc.). Another is that the focus of the individual groups and organisations varies considerably. Whereas some focus on climate protection and go into detail on the different solutions proposed, others have a broader range of goals and give more weight to issues such as local ecology and competition with renewables.

The World Wide Fund for Nature (WWF) advocates CO₂ storage under certain conditions (WWF 2005, 2004):

- No storage in oceans, open aquifers or lakes,
- International monitoring of storage must be introduced,
- Public funding of research into CO₂ storage should have no influence on the level of research funding for renewables,
- Emissions trading: only developed countries with 'CO₂ caps' should be allowed to offset 'carbon capture and storage',

- CCS should complement rather than substitute for the expansion of renewables.

Another reason why the WWF takes a positive view of the role of CO₂ storage is because it sees it as a stop-gap that can be used until other technologies have been developed sufficiently to be able to make a decisive contribution to CO₂ reduction.

Greenpeace generally rejects CCS, but in the event that CO₂ capture and storage should be introduced Greenpeace believes it should be used as an additional option and not as a substitute for expanding the use of renewables and introducing energy saving measures. In addition a number of 'essential conditions' must be fulfilled (Greenpeace 2004, 2007):

- CO₂ storage sites must be leak-proof for several thousand years,
- CO₂ should be stored only in disused oil or natural gas fields; no storage in oceans, coal seams or salt domes; storage in saline aquifers only after careful examination of safety aspects, potential utilisation conflicts and environmental impact,
- No use of CO₂ for EOR and EGR,
- Drawing up of national, European and international guidelines regulating CO₂ storage,
- CCS should not be offset under the Clean Development Mechanism (CDM),
- Emissions trading: still a need to discuss whether CO₂ storage should be included,
- Research and development: public research funding should be used exclusively for research into storage facilities (because safety is in the public interest),
- Export of the technology only after safe use in industrialised countries has been proven.

Above and beyond this Greenpeace sees no requirement for CCS in industrialised countries (Greenpeace 2005).

Climate Action Network (CAN) is an umbrella organisation of more than 350 NGOs active in climate protection world-wide. In May 2006 CAN Europe published its position on CCS, much of which corresponds with that of many other NGOs: no disposal of CO₂ in the oceans, priority to be given to renewables and energy efficiency (e.g. in the area of research funding) and authorisation of CCS only after it has been proven that (geological) storage facilities are leak-proof in the long term. CAN also regards the development of a legal framework (operator liability for leaking storage facilities, no burden on public budgets) as an essential prerequisite for the introduction of CCS (CAN 2006).

Compared with those in other countries, German NGOs tend to take a rather sceptical attitude to the storage of CO₂, but they have no uniform position on the matter. They all agree, however, that top priority must be given to expanding the use of renewables and to more rational energy use. This position stems from the fear that funds for CCS research might be made available at the expense of research in the fields of renewables and energy efficiency.

Specifically, the following reasons or fears have been named:

- CCS constitutes a classic ‘end-of-pipe’ approach, where problems higher up the process chain (those associated with the supply of fuel) are not only not solved, but tend to be aggravated (e.g. environmental damage caused by open-cast lignite mining) (NABU 2005).
- CCS offers ‘no solution to the problem of providing a sustainable supply of energy’ because of the large volume of additional energy required, an underestimation of the dangers of ‘permanent disposal of CO₂’ and high costs. The use of CCS, it is argued, will prevent a switch of the energy system towards energy efficiency and renewable energies (BUND 2005, 2006; Robin Wood 2006).
- There are still too many open questions regarding the quality and quantity of storage sites. In addition the long periods of time that would have to be bridged until a large-scale system of storage is established make the actual contribution of CO₂ storage to a reduction in emissions seem questionable (Germanwatch 2004).

3.2 Industrial Associations and Companies

In a statement on capture-ready concepts the European Power Plant Suppliers Association (EPPSA 2006) gives recommendations for the use of CCS technology at power stations: ‘Efficiency improvement is the least costly method for direct CO₂ reduction and also minimises the capital and operation costs for the CO₂ capture equipment by reducing the flue gas/ CO₂ volume that the equipment needs to handle ... The authorisation process should allow the plant to run with or without CO₂ capture.’

Associations representing the interests of the coal industry in various countries fear that a reduction in supplies and market share motivated by environmental and climate protection considerations will have a negative effect on turnover and employment in the coal industry, so these traditional sectors of the energy economy are among the most active promoters of CO₂ capture and storage. The coal industries in Poland and

Spain, for instance, are among those in a number of countries that advocate the use of large-scale technology for CO₂ storage.

Oil and gas producers see CO₂ capture and storage as a promising additional business opportunity in the future. For this reason companies like Shell, BP and Statoil are among the advocates of CO₂ capture and storage. Initial practical steps have already been taken; CO₂ is already being pumped into oil fields in order to raise the yield of oil.¹ This is made additionally profitable in some cases, as already explained, by the existing tax on CO₂. Thus in this respect CO₂ storage generates direct economic profits (Williams 2003). In addition today’s oil and gas producers could in future become important suppliers of potential CO₂ storage sites in the form of disused oil and gas fields.

To date few German industrial associations have produced position papers stating their position on CO₂ storage. Those that have include the German Lignite Industry Association (DEBRIV), which advocates the capture and storage of CO₂, as well as the German Coal Mining Association (GVSt) and the Association of German Engineers (VDI). The GVSt and the VDI call for clarification of this ‘long-term option’, but their main priority is a maximum increase in the efficiency of the power plant process as a contribution to climate protection (RWE Rheinbraun / Vattenfall Europe 2003).

3.3 German Political Parties

Germany’s political parties take different positions on CCS. The current governing coalition of conservatives (CDU/CSU) and social democrats (SPD) is positive about carbon capture and storage. The CDU sees CCS as a means of reducing carbon dioxide emissions worldwide and therefore advocates further research efforts in this field. Both the CDU and the CSU describe low-CO₂ fossil fuel power stations as ‘important cornerstones’ of their energy policy (Union 2002). The SPD calls for ‘... a co-ordinated research offensive for low-CO₂ or CO₂-free power stations (CO₂ capture)’ (SPD 2003).² The liberal party, FDP, sees the capture and storage of carbon dioxide as an option for emissions reduction (FDP 2003). **Alliance 90/The Greens** believe that CCS is currently too immature a technology to provide any justification for increasing the number of coal-fired power stations in Germany (B90/Grüne 2003). **The Left Party**, on the other hand, comes to the conclusion that there is no place for ‘coal-fired power stations, however “vision-

1 As in the Norwegian Sleipner field, this CO₂ often appears as a by-product of oil and natural gas extraction and is injected back into the formation (EOR/EGR, enhanced oil/gas recovery).

2 ‘eine koordinierte Forschungsoffensive für CO₂-arme bzw. CO₂-freie Kraftwerke (CO₂-Abscheidung) ...’

ary” their technology is’ in its demand for a complete switchover to a renewable energy system by 2050 (PDS 2004).

3.4 German Ministries and Expert Committees

3.4.1 The Federal Ministry of Economics and Technology (BMWi)

The Federal Ministry of Economics and Technology is supporting carbon capture and storage with its research program COORETEC. This broad research programme is intended to provide a high-tech basis for meeting the need to replace old fossil-fuelled power stations by new ones. One branch of research in this programme is the long-term development of low-CO₂ power plants (misleadingly called ‘zero emission power plants’) (Rüggeberg 2004).

3.4.2 The Ministry for the Environment, Nature Conversation and Nuclear Safety (BMU) and the Federal Environment Agency (UBA)

Despite numerous research efforts, the Federal Ministry of the Environment and the Federal Environment Agency still have many open questions about the long-term safety and social, ecological and economic acceptability of CCS. Specifically there has so far been no systematic examination of CCS as a whole in the form of an ecological evaluation, an analysis of possible interaction with other aspects of the energy economy or a comparison with other measures for the reduction of CO₂ emissions – which is the main justification for the current research project. In August 2006 the Federal Environment Agency published a position paper entitled: ‘Separation and Storage of CO₂ – only an interim solution – possible effects, potential and requirements’, which examined the extent to which the introduction of CCS would be compatible with sustainability requirements, particularly in Germany (UBA 2006). In line with the guiding principles for sustainability issued by the Enquete Commission for the ‘Protection of People and the Environment’ of the thirteenth German Bundestag, the following theses were developed:

1. Climate protection can be achieved using renewables and energy efficiency. The technical capture and storage of CO₂, on the other hand, is not sustainable and is therefore at best an interim solution.
2. Capacity for CO₂ storage should be the main focus of discussion: in Germany this may be limited to forty years.
3. Technical capture and storage of CO₂ involves costs. Assuming ambitious climate protection goals, some projects will probably be economically viable.
4. CO₂ storage facilities should not exceed a leakage rate of 0.01 % per year. Dangers to health and environment should be avoided.
5. Storing CO₂ in the oceans and the ‘artificial mineralisation’ of CO₂ cannot be considered options.
6. A national and international legal framework must be developed for CCS.
7. The discussion should include environmental issues and questions of equity. Research, state regulation and demonstration projects should not be limited to technical aspects alone.

Altogether the UBA advocates initiating a more far-reaching discussion of sustainability issues in order to add a sustainability dimension to a ‘discussion that to date has been conducted mainly with a view to technical aspects’. The results of the ecological and economic calculations done within the current project offer a preliminary basis for a concept of this kind and should be included in any fundamental discussion of sustainability.

3.4.3 The Council for Sustainable Development (RNE)

In a position paper the Council for Sustainable Development calls the capture and disposal of carbon dioxide a possible important bridge ‘on the way to the era of renewable energy supplies’. Here it recommends integrating technology for CO₂ capture in high-efficiency power stations, only, however, from the point of view of economic efficiency. If this goal is not attainable, fossil-fuelled power stations should not be part of a long-term strategy for a sustainable energy supply. While the Council for Sustainable Development advocates research into technology paths of this kind, this must not compete for research funds in a way that might give priority to this end-of-pipe technology over research into renewables and improved energy efficiency. The Council for Sustainable Development lists CCS as a field of research along with research into renewables, energy efficiency and material efficiency (RNE 2004).

3.4.4 Advisory Council on Global Change (WBGU)

The Advisory Council on Global Change (WBGU) set up by the German government has taken up a clear position on the storage of carbon dioxide. It refers to CCS as an ‘end-of-pipe technology’ and states: ‘Fossil fuels will continue to be the dominant source of energy in many countries for decades to come ... Therefore the end-of-pipe technology for carbon storage provides ... an option for climate protection.’ (WBGU 2003). The criteria for evaluating various options include length of storage, storage safety and environmental impact. WBGU rejects as storage options disposal in the oceans (ecological reservations), terrestrial sinks/biomass

(lack of potential for expansion) and saline aquifers (no guarantee of safety and long-term storage). With regard to the length of storage the WBGU concludes in its most recent report (WBGU 2006): 'Sequestration ... only represents an acceptable climate protection technology if it can be guaranteed that CO₂ will remain in a deposit for at least 10,000 years.'

Disused oil and gas fields could be used for interim storage, but only if the retention period mentioned above could be guaranteed. In the opinion of the WBGU there is a need for further research, above all on the permanent storage issue (WBGU 2003). Under certain conditions storage under the seabed might also be a feasible option. The WBGU recommends regulating CO₂ storage under the seabed and proposes a number of instruments for this purpose:

- The formulation of minimum standards,
- Direct volume limitations: in international climate protection agreements stored volumes of CO₂ should not be counted in full as avoided CO₂ emissions,
- The establishment of liability mechanisms.

In principle the WBGU advocates sequestration under the sea floor, however only for 'a transition period as an additional option to more sustainable emissions avoidance strategies' (WBGU 2006). It further recommends, 'clarifying the question of the compatibility of CO₂ storage under the sea floor with the London Convention or the London Protocol ... in such a way that CO₂ sequestration in geological formations ... is permissible' (WBGU 2006). At the same time the WBGU calls for such activities to be limited to a certain period of time (several decades), thus underlining its statement that CCS should only constitute an interim solution. The WBGU believes it would be sensible to apply flexible mechanisms to sequestered CO₂ as well, although within the above-mentioned constraints.

3.4.5 Advisory Council on the Environment (SRU)

The Environmental Council believes that the capture and storage of carbon dioxide may be too expensive in comparison with other emissions avoidance options. An additional reservation is that 'even its advocates think that it will not be realisable until after 2020'. This would mean that this technology would come too late for the upcoming renewal and expansion of power station capacity (SRU 2004, 2000). The SRU is keeping track of this issue and continues to see a great need for action with regard to making a comprehensive evaluation of this technology (Hey 2006).

3.4.6 Office for the Assessment of the Impact of Technology of the German Bundestag (TAB)

As part of its monitoring of 'the sustainable supply of energy' the TAB has addressed the issue of 'CO₂ capture and storage for power stations'. A study surveyed the existing literature on the subject and a workshop of experts was held to identify critical gaps in knowledge and to 'define areas in which a more profound analysis can be undertaken' (TAB 2006).