Discussion Paper 7

Carbon Capture and Storage:
Settling the German Coal vs. Climate Change Dispute?

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1 Introduction

Coal is Germany's major domestic energy resource and electricity generation input. The country is a major lignite producer, while hard coal mining has declined in favour of imports. Altogether, coal provides almost 52 % of the fuel inputs for electricity generation. Under business as usual conditions, this picture is unlikely to change in the near future.

With regard to sustainability, the extraction and combustion of hard coal and lignite for electricity generation is a heatedly debated issue. Coal proponents claim that coal use ensures security of energy supply at low cost. Under the conditions of a nuclear phase-out, they see no alternative to it. Environmentalists argue that coal mining and combustion are responsible for landscape destruction and that they threaten the earth's climate more than any other single energy source.

Carbon capture and storage (CCS) could be considered to be an innovative approach to these issues. CCS promises to enable the low-emissions coal power station. However, the technology is unlikely to be available before 2020 and it remains unclear at what cost. Also, storage capacities are limited.

The innovation of CCS takes place in a special socio-technical context: The electricity system can be characterized as a "Large Technological System" (Hughes 1983) Such a system is composed of an enormous set of technical and non-technical components, all interconnected both horizontally and vertically. Unsurprisingly, such a complex system involves a high degree of inertia and barriers to change on all levels – technology, institutions, and in particular actors. Such a system allows for incremental innovations a best. Correspondingly, fossil fuel-based electricity generation benefits from a long-standing, specialized and pervasive network of proponents, holding enormous technological, economical and knowledge assets, thus hin-

dering the innovation and diffusion of new carbon-free technologies. Prospects for escaping this "carbon lock-in" are unfavourable at present (Unruh 2000; Unruh and Carillo-Hermosilla 2006; Perkins 2003).

Carbon Capture and Storage (CCS) could be an innovation that paves the way out of the lock-in situation. At first glance, it is an incremental innovation, representing a change *within* the existing system that does not endanger (or that even reinforces) its overall structure. CCS allows for the continued use of fossil fuels, it can be combined with the existing infrastructure (that is, large-scale centralized power plants) and implemented by existing actors. Opponents therefore fear that CCS may further delay the urgent transition to a carbon-free electricity system. But in the long run, CCS could be an innovation that “buys time” for radical restructuring and serve as a bridging technology towards a sustainable energy future.

Hence, two questions emerge. First, will CCS stand a chance to be implemented at all? Secondly, if it is implemented, where will its implementation lead? Which policy choices will be associated with CCS? Which place in the overall electricity system will it occupy? Will it be used to prolong the fossil fuel system, or to provide a bridge towards a low-carbon future?

In our understanding, answers to these questions depend heavily on the system of actors that generates energy policy choices. There is much agreement in political science on the fact that in modern societies, policy outcomes are determined by the interaction of a number of individual and collective societal actors, each with their respective interests, values and power resources. These actors establish more or less strong, durable or co-operative ties and channels for information and resource exchange between them, forming webs that (depending on the theoretical outlook) might be labelled as "sub-governments", "policy communities", "advocacy coalitions", "policy networks" or "issue networks". State agencies and politicians are but one in this web of actors and often not the decisive one. (Marsh 1998).

With respect to carbon capture and storage, apart from a – limited – R&D programme, no elaborated policy exists in Germany so far. Rather, the process is in the agenda setting phase where issues for discussion and, potentially, decision making are brought to the fore. We contend that, in this phase, identifying the relevant actors and determining their interests, visions and resources as well as the ties and interactions between them, will help to understand and delimit possible courses a future policy may take.

Hence, our paper sets out to explore whether the emergence of CCS technologies changes the political agenda for the future German coal-to-electricity system. Does CCS availability bring new policy and system options to the fore? Which of them can gain political support? Special attention is given to the future of coal, to the integration of coal and CCS into the future energy system as a whole, to the desired political instruments and framework for shaping future electricity policy and to timing aspects.

For this purpose, we portray the actor constellation in the German coal-to-electricity system. We identify the setting, interests and views of the actors, networks and coalitions in this policy field. Subsequently, we analyze possible changes in the constellation that may result from CCS availability.

Though discussions decisions on CCS are of course embedded in an international context (markets for coal and CCS technology, information flows, international technological development, EU policies), our analysis focuses on the national actor system. Even today, core energy policies and other policies relevant for CCS (such as R & D funding, environmental regulation or allocation of emission rights) are decided upon on a national level. Investment decisions are made in the light of national policies and energy needs. It seems therefore sensible to chose the national actor system as the unit of analysis. EU policies, international mar-

kets, cooperation and communication channels are taken into account as far as they form a relevant framework for national actors' strategies and interests.

The core methodical challenge in such a task is to identify the relevant actors. To do so, we combined three approaches. First, an *institutional* approach points to the actors that are assigned formal roles in the policy-making process. These comprise the actors involved in legislation and programme-making, namely ministerial departments and parliamentary actors, but also various consultative bodies set up by the government. Secondly, an *interest-based* approach identifies all organized societal actors that might be affected by the respective policy and therefore can be expected to release lobbying efforts and stimulate the public debate. Thirdly, a *relational* approach consists in asking actors already identified about which other actors they view as important in the respective policy area. This way, we could establish a consistent set of relevant actors. (see Jansen 2003, ch.4, for details on network identification.)

We based our research on written documents, on observation, and on 29 interviews. Written documents included newsletters, published position and discussion papers, websites and journals of relevant actors as well as public speeches that were documented in the above media or available on demand. In addition to information collection from publicly available sources, all actors were asked to provide relevant written material expressing their positions or activities. Observation meant the participation in three workshops organized by the Wuppertal Institute, BP, and the Green Party, in which a number of actors were present and gave their views. Interviews were conducted personally, on the telephone, or in a few cases via email.[1] Issues included the interviewees' assessment of the chances and risks of CCS, their goals and activi-

[1] A full list of sources is available in our respective Discussion Paper at http://www.tips-project.de/download/TIPS_DP7_ccs_paper2005.pdf.

ties in this field, their forecasts and wishes for a future electricity system (especially the role of coal and of CCS within it), their requirements for a political framework for coal and CCS, their assessment of relevant actors in the field of CCS, and their communication and cooperation or conflict with other actors.

The main analysis was conducted in summer 2005. In fall / winter 2005, the draft paper was communicated to the actors interviewed, and some provided comments that were included in the final version. In fall 2006, we did another literature research, reviewed current developments and updated the article, where necessary.

Section 2 summarizes the major features of CCS and outlines the resulting questions and challenges which actors are facing when discussing CCS and coal. In Section 3 we provide a detailed description of the actor constellation, followed by a concluding discussion in Section 4.

2 Coal and CCS: What Are the Issues at Stake?

To date, CCS is at an early stage of development and market formation, leaving several decisions to be made and a number of questions to be asked. This section gives a brief overview of the current state of CCS technology, its economics and its environmental performance. From this, we procure some issues coming up in the debate about a future deployment of CCS. A detailed assessment of the current status of CCS is presented in the recent IPCC report (IPCC 2005).

2.1 CCS characteristics

The technologies and practices associated with carbon capture and geologic storage have been in commercial operation within various industries for 10 to 50 years (Curry 2004). The oil industry, for example, has been injecting CO_2 into oil formations to recover additional oil since the 1970s (so-called enhanced oil recovery or EOR). A network of pipelines was built in

the Western USA in order to connect CO_2 emission points and oil drilling places. One of the main differences between EOR and CCS is that the former is not concerned about the long-term fate of the injected CO_2. Leakage is, therefore, not an issue and neither is liability. R&D is thus needed on its technological integration into the electricity generation process and particularly on leakage and storage issues.

Technology. In electricity generation, CCS is possible for a number of fuel inputs. However, due to differences in fuel prices, the debate has been focusing on CCS from coal-based power plants; it is not likely to be economic in gas plants. Several CCS processes are currently being developed: capture from the flue gas (*post combustion*), separation from the fuel gas (*pre combustion*) and *oxyfuel technology*, in which the fuel is combusted with pure oxygen, producing a high concentrate of CO_2 which facilitates its recovery. Post combustion is available for conventional power plants, pre-combustion is applied in integrated gasification combined cycle plants (IGCC). Retrofit is only possible for post combustion. Technologically and economically, IGCC appears to be the most promising (Watson 2005, Radgen et al. 2006). In Germany, the first 30 MW oxyfuel pilot plant is being conducted by the energy utility Vattenfall and is to be completed by 2008 and then followed by a demonstration station of 200 MW. RWE announced, meanwhile, that they are to build an IGCC plant of 450 MW by 2014.

Transport and Storage. The captured CO_2 can be compressed and led through pipelines or by ships or other carriers to the storage site in, e.g., saline aquifers, oil and gas fields or coal seams. The disposal of CO_2 in deep oceans is currently not regarded as an option in Europe,

including Germany.[2] Its risks, particularly in terms of the time of storage and effects on the marine environment, are considered to be too high (WBGU 2003).

In Germany, saline aquifers have the greatest storage potential. The total theoretical storage capacity in Germany is estimated to be in the range of some 80-150 years, if all CO_2 from power plants (about 320 Mt/a) is to be stored (COORETEC 2003; GESTCO 2004). Actual technical and economical capacities are lower, depending on geological restrictions, cost and the location of the storage sites. Moreover, as many storage sites are cross-national, the distribution of rights and responsibilities requires clarification.

Leakage and the energy penalty. The major environmental risk (and perversion) of CO_2 storage is leakage. Model calculations and natural analogies suggest that in many geological formations, leakage rates below 1 % over 1,000 years are possible. Exhausted gas and oil fields and, to a lesser extent, salt caverns have been so far regarded as safe permanent storage sites. However, any leakage rate greater than zero means that most of the CO_2 stored will have escaped some day. Therefore, liability for expected or unexpected leakage is an issue to be debated. Doubts about storage safety have been fuelled by a recent US study showing that stored CO_2 can dissolve minerals in the ground and, by this means, cause leakage (Kharaka et al. 2006).

The second major drawback of CCS is its negative impact on power plant efficiency. For conventional hard coal plants, the conversion efficiency decreases between 8 and 12 percentage points, for IGCC between 6 and 8 percentage points (Schumacher and Sands 2006). This

[2] However, the US and Japan are considering ocean storage, and international legal barriers have been recently changing the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, so that CO_2 no longer counts as a pollutant (Point Carbon, 2006).

figure increases even more when a life cycle analysis (LCA) of all up- and downstream processes is conducted (Idrissova 2004; Pehnt 2005). Both – leakage and conversion efficiency – are significant parameters for the global warming balance of CCS. Efficiency losses also increase fuel consumption and associated environmental damage such as landscape destruction and pollutant emissions.

Economics. The market potential for CCS depends mainly on how economical the process is compared to other CO_2 reduction strategies (DIW 2005). Carbon capture increases the cost of coal-based electricity generation because of the additional plant equipment and the "energy penalty". The latter is smaller for pre- than for post-combustion processes, with corresponding economic effects. In the relevant literature, the range of estimated costs is great, depending on the underlying assumptions, in particular those on investment costs, conversion efficiencies, future interest rates, fuel prices and the cost of CO_2 emission certificates.

Due to the comparatively high cost of retrofit, CCS is more likely to be implemented in new power plants once it is commercially available. CCS could be economically viable at a CO_2 price in the range of 30 to about 50 EUR/t. For conventional hard coal plants, CCS would increase the costs of electricity generation by about 3-4 cents (EUR) per kWh; for IGCC the increase amounts to about 2-3 cents. At a carbon prize range of 25-35 EUR/t CO_2, renewable-based electricity production can compete well with CCS (Schumacher and Sands 2006, based on IEA 2004; WI et al. 2004a). This is in accordance with estimations of IPCC (2005).

Thus, whether CCS will make economic sense first and foremost depends on the existence and level of carbon prices and the corresponding climate policy goals. The degree to which it will be able to compete with renewable energy sources remains an open issue. In any case, commercial availability is not expected any earlier than 2020 and CCS will be most competitive for large, centralized power plants, ideally located close to the storage location. Corre-

spondingly, the economic potential of CCS to contribute to climate change mitigation remains limited to the share of electricity generated centrally.

2.2 Resulting Challenges

In the face of the above features, actors involved in the debate about the future role of coal and CCS for electricity generation in Germany are confronted with numerous issues. In short, two separate but interlocking concerns can be distinguished: first, the potential impact of CCS on the future electricity system, and secondly, the policies to shape the path towards the future.

Potential impact on the future energy mix. A first question is in which direction CCS will affect the absolute and relative shares of lignite and hard coal. On the one hand, coal may benefit from the reconciliation of coal combustion and climate policy that CCS promises. On the other, CCS costs might negatively impact on coal's competitiveness. Both depends on the development of the price for CO_2 emission certificates.

Secondly, CCS might affect the degree of centralization of the future system: as it is only feasible for large point sources of emissions, it may be at odds with a more decentralized structure of renewable technologies. A related pressing concern is whether CCS might be implemented in such a way that it functions as a "bridge" instead of hindering other sustainable technologies, e.g. renewables, from diffusion into the existing system. Similarly, the question arises how to synchronize CCS with the investment cycle for power plants. CCS will probably not be available before 2020. Observers expect that by this time some 40 GW of capacity will already have been replaced in Germany, due to the expected phasing-out of nuclear energy and the decommissioning of further plants (Umweltbundesamt 2003, p.10; Matthes and Ziesing 2003, p. 13f). Retrofit is less cost-effective than integrated CCS and is not considered an attractive option. The question is, therefore, whether CCS will simply come too late.

Policy options and needs. A variety of policies and measures would need to be introduced if CCS is to be developed technologically and supported in its market introduction. Among the most-debated issues are the level and intensity of public R&D funding for CCS as compared to other (renewable) energy or climate change mitigation technologies, and the regulatory framework needed for safe storage. Above all, climate policy builds the framework for any activity and impacts on the economic performance of CCS via the resulting carbon price. Also, international diffusion of CCS depends on its inclusion in the portfolio of technologies accepted for the flexible instruments of the Kyoto Protocol (JI and CDM).

Public acceptance. In addition to these concerns, public acceptance is the great unknown at the moment. A major fear articulated by potential investors is that the storage of CO_2 may trigger an avalanche of public protest activities, similar to those observed in the case of nuclear energy. This aspect will be treated in more detail in Section 3.1.4 below.

3 Coal and CCS: Changing Actor Constellations?

CCS is still in an early stage of development, a fact that finds its reflection in the structure of actors involved in this area. Globally, more than 60 % of actors involved in CCS are situateed in research institutes and universities. In Germany, about two thirds belong to R&D institutions, with the remaining one third stem from industry (Radgen et al. 2006). In the following sections, we discuss the setting of actors involved in developing and implementing CCS. Based on our interviews, we provide an overview of their interests and positions. First, we describe the actor constellation. We will then summarize which lines of consensus or dissent emerge in issues that are of particular interest to actors. Finally, we assess whether the discussion about CCS brings about changes in the constellation that may affect the future of coal.

3.1 The Actor Constellation in Germany

3.1.1 CCS Activities

The last few years have witnessed a growing level of activities around CCS both nationally and internationally (Radgen et al. 2006; Linßen et al. 2006; European Commission 2004). In Germany, most activities focus on R&D, with the electricity utilities Vattenfall and RWE as the only actors with actual investment plans to date. In its current energy research program, the Federal Ministry for Economics and Technology (BMWI)[3] supports R&D in CCS and power plant efficiency with an input of EUR 284 million from 2005-2008. The program is based on the COORETEC (CO_2 Reduction Technologies) concept developed by the ministry in cooperation with industry and science (BMWI 2005 p.24-27; BMWI undated). The Federal Agency for Geosciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe, BGR) is involved in 13 projects on storage possibilities and storage safety. In September 2005, the Federal Ministry of Education and Research (BMBF) national programme "CO_2-Storage in Germany" in the framework of the R&D-Programme GEOTECHNOLOGIEN It includes ten research projects, worth almost EUR 8 million altogether, treating different aspects of storing CO_2 underground (Stroink 2006).[4] Almost 6.7 million are provided by the BMBF, 1.3 million by participating firms.

While these programs focus on technological R&D, the Federal Ministry for the Environment (BMU) is running a more policy-oriented project for evaluating CCS and comparing it to renewable energy technologies from a climate-policy perspective. The program includes a dialogue between different actors by means of a number of workshops (WI et al. 2004b). The

[3] At the time of the program launch: Federal Ministry of Economics and Labour (BMWA).

[4] See website www.geotechnologien.de.

Federal Office for the Environment, the central scientific body of BMU, also assessed CCS technologies (Radgen et al. 2006) and formulated a position paper, concluding that CCS could, at the utmost, be considered a bridging technology (Umweltbundesamt 2006). However, compared to other research topics, and even to renewable energy, CCS today accounts for only a small share of total energy R&D expenditures (BMWI 2006).

Furthermore, European initiatives are an important framework for German activities. On the European level, R&D in CCS has been increasingly supported by EUR 16 million within the 5th EU Framework Program for Research (FP) and by EUR 70 million within the 6th FP (Dimas 2006a).[5] On December 1st, 2005, the European Commission in cooperation with major industrial associations launched the Technology Platform for Zero Emissions Fossil Fuel Power Plants (ZEFFPP, later ZEP).[6] It brings together actors from industry, research, NGOs and the European Commission in an effort to develop a "Strategic Research Agenda" and "Strategic Deployment Plan" for CCS as an input to the 7th FP (European Commission 2006). In fact, one of the priorities announced for the 7th FP are the "Zero-emission power-plants" and the research, development and demonstration activities connected to these plants (Dimas 2006a, 2006b). Besides, Germany has been engaged in the Carbon Sequestration Leadership Forum (CSLF), a ministerial-level international initiative for CCS development, since 2003.

[5] Jürgen Levefre, Policy coordinator on international climate change at DG Environment, in contrast, mentions 75 Million EUR EU funding in FP 5 and 6 (Lefevre 2006)

[6] See website at http://europa.eu.int/comm/research/energy/nn/nn_rt/nn_rt_co/article_2268_en.htm, last accessed 2 April, 2006.

3.1.2 Overview of Actor Groups

Most of these activities are rather recent. For a long time, CCS had not been much of a political issue in Germany. The debate had been taking place in expert circles, involving a relatively limited set of actors. The main drivers were research organizations, the oil and gas industry and a few political bodies such as the Federal Ministry for the Economy and Technology (BMWI) and the German Council for Sustainable Development. The oil and gas industry, albeit not directly involved in electricity generation, has longstanding expertise in using CO_2 for enhanced oil recovery and would benefit from CCS with a double dividend: first, by receiving CO_2 for EOR and secondly, by selling off the related CO_2 certificates.

Now the time seems ripe for more actors to join in. In the face of rising oil and gas prices, recent turbulences about Russian gas supplies, and a new centrist government seeking to coin its own profile in energy policy, energy security is on the agenda again. The Chancellor herself invited stakeholders to an "Energy Summit" on April 3rd, 2006. At the same time, climate policy is re-emerging as an issue: the negotiations for the second commitment period of the Kyoto Protocol are beginning, climate has been a topic at G8 summits and recent flood events have heightened public attention. And finally, CCS technology is making progress and is being recognized on an international level by the climate policy community, as shown by the recent IPCC report on the issue (IPCC 2005). In this vein, political interest in CCS is beginning to increase and the debate has been gaining considerable momentum lately.

This is especially so in the case of electricity and power plant industry and environmental NGOs. For some time, electricity and power plant industry had shared a pattern of arguments with coal mining industry, called the "Three-Step" or "Three Horizons" concept. It stipulated that fossil fuels should be made more climate-friendly in three steps: first, apply existing "best practice" technology (and export it worldwide); secondly, develop new power plants with increased conversion efficiency; and thirdly, explore possibilities for CCS. CCS was thus pre-

sented as a technology for the rather remote future. The main reason behind this reluctance was the expected loss in conversion efficiency and increase in cost. Industry was involved in R&D activities in order to keep up-to-date but kept its engagement rather low key, called for public funding as a condition for an own investment, and did not do much to publicly promote the technology.

With rising natural gas and the possibility of carbon prices also rising, CCS is slowly becoming more attractive. The three biggest electricity companies, E.on, RWE and Vattenfall, and the power plant constructor Siemens PG now have key roles in the EU Technology Platform on Zero Emissions Fossil Fuel Power Plants (ZEFFPP / ZEP). They are also involved in a number of projects within the GEOTECHNOLOGIES Program. Ten months after Vattenfall announced the construction of an oxyfuel demonstration plant in May 2005, RWE outplayed them in March 2006 by announcing the construction of an industrial-scale IGCC plant with CCS. The "Three-Step" concept is still used in public communication but is being modified to endorse CCS in a more committed fashion.[7]

One might expect that prospects for international markets stimulate electricity industry's activities. This is also voiced by some interview partners, pointing, for example, to China's future energy need and its expected rise in the use of coal. However, the factual level of commitment seems to be dominated more by national considerations: it neatly corresponds to the share of coal-based generation in electricity companies' German portfolio. Vattenfall Europe, initiator of the first publicly visible project, generates some 77% of its electricity from domestic lignite (Vattenfall 2004, p.6). RWE Power, which followed, has a share of 66% (hard coal 26%, lignite 40%) (RWE 2006, p.116). E.on, which has not yet issued its own project but is

[7] See, for example, the recent RWE presentation, RWE Power 2006.

engaged in R&D cooperations, had a share of 48.8 % in 2004 (26.1 % hard coal; 22.7% lignite) (E.on 2005, p.40). EnBW, which has no profile in the issue, does not disclose its coal share but does have only a 23.8% share of fossil fuel generation, including oil and gas (EnBW 2005, p.111). International markets seem to be more of a theoretical argument, since the biggest future coal users (like China) do not have climate commitments so far and it remains an open question to what degree they will be interested in climate technology.

Within power plant industry, interest is also accruing. ALSTOM wants to develop a capture method for the oxyfuel process, while Siemens is focusing on IGCC technology. However, they feel that there are uncertainties because they essentially depend on the decisions of electricity industry.

Environmental NGOs have also been making up their minds recently. As of summer 2005, only Germanwatch, Greenpeace and WWF had adopted a clear position. Recently, they were followed by Friends of the Earth Germany (BUND) in February 2006 and by the Climate Action Network (CAN), a European network that includes a number of German NGOs, in October 2006. The Nature Protection League (NABU) has formed a position but not in written form so far. In the face of the rather complex issue, NGO positions have become more diverse as the discussion has gone on.

The general tendency is to formulate quite stringent preconditions for CCS use and to strictly prioritize renewable energies and energy efficiency over any fossil fuel source, whilst admitting (or at least implying) that CCS might be a possible emergency or bridging option to protect the climate in case other attempts fail and the preconditions are fulfilled. Germanwatch and NABU express the most clearly that CCS might even be desirable and demand that every new coal plant in Germany should be equipped with CCS or prepared for retrofit. Germanwatch argues that CCS might be the only solution for rapidly industrializing countries. On the

other side of the spectrum, BUND clearly rejects CCS. The organization fears that CCS might be used to prolong fossil fuel use with all its negative environmental effects and sees it as a "fig leaf" for coal industry.

The latter is, surprisingly, remaining rather passive. Associations which represent traditional coal and lignite mining industry (like DSK, GVSt or DEBRIV), as well as electricity generators who rely on coal (like STEAG), have not been strongly promoting CCS. Some even refused to comment on the issue. In publications, they endorse the above-mentioned "Three-Step" concept. From our interviews, some possible reasons emerge: first, in the case of hard coal, it is a question of task sharing between coal miners and traders on the one hand and electricity industry on the other. Mining industry leaves it to power industry to deal with an issue which is ultimately so closely related to power generation. Secondly, climate protection has never been much of an issue for mining industry. Their main arguments for an extended use of coal revolve around its easy availability and the security of supply which it promises to deliver. Finally, CCS creates additional costs for power generation from coal which may undermine its competitiveness.

While electricity and power plant industry as well as NGOs have become more active, other groups of actors remain essentially silent. The issue is only slowly moving into debates within parties or in parliament, and only recently, parties start to articulate active positions. In April 2006, for example, the CDU/CSU suggested CCS to be a major focus of their initiative "ZukunftEnergieForschung" (Future Energy Research) (Donner and Lübbers 2006). Positions in the Green party, as articulated in interviews and during a workshop organized by the party in early December 2006, more or less mirror the spectrum within the environmental movement: they range from very critical to some interest with slight reservations. A first minimum consensus was reached in a resolution from 6 November 2006, where the party declares that future investments in coal-fired generation plants should only be approved when they apply

CCS (Grüne 2006). Social Democrats, traditionally attached to coal industry, would like to reconcile coal use and climate protection (which might be one of the reasons why the SPD-led BMWA has been pushing the case) and target at the emissions-free power station. Liberals and Socialists have no strong case yet, with the latter being rather sceptical while the Liberals support R&D initiatives.

Like the majority of the parties, trade unions are remaining on the back seat. Although the debate has been accelerating, CCS has thus not yet completely left the expert circles and entered the realm of public debate.

Table 1 very briefly summarizes the actor groups engaged in CCS policy in Germany. Based on an in-depth analysis of selected organizations from each group, it shows the strategic interests, general attitudes and activities of different actors with respect to CCS.

3.1.3 Influence of Actors

To determine which actors are influential, we assessed their resources and the linkages between them. By linkages we mean communication, co-operation and exchange of financial, informational or human resources. Actors who provide others with resources are generally more influential than resource-dependent actors. Also, co-operation generally increases influence; communication channels can also be an important source of influence for otherwise resource-poor actors.

The interesting thing about CCS is that different types of resources are unevenly distributed across actors. *Industry* (including electricity, power plant, and oil and gas industry) possesses substantial funds and the formal power of decision-making on investments. On the other hand, due to the uncertainties related to CCS, industry depends on *researchers* to provide vital information and on *policymakers* to reduce the financial risk by constructing a calculable policy framework and providing additional R&D funds. Within the political system, *ministries*,

Table 1: Actor groups in the CCS policy process

Actor group (and showcase examples analyzed in this study)	**General attitude**	**Basic interest / concern**	**Activities**
Environmental organizations Climate Action Network (CAN), Bund für Umwelt und Naturschutz Detschland BUND (Friends of the Earth Germany), Germanwatch, Greenpeace, World Wide Fund for Nature (WWF), Naturschutzbund NABU (Nature Protection League)	Mixed; generally critic	CCS as potential climate protection backup option, but high risks: "fig leaf" for prolonged coal use; environmental and safety issues, competition for R&D with renewables. Rebuttal of ocean storage. But open to dialogue, only a few reject CCS upfront.	Position papers, taking part in consultation processes, partly organizing workshops.
Electricity Industry (power producers) Energie Baden-Württemberg EnBW, E.on, RWE Power AG, Vattenfall, Verband der Großkraftwerksbetreiber VGB Power Tech (Alliance of Large Scale Power Plant Operators),	Mixed; partly proactive; partly ambivalent;	CCS as possible future option but many uncertainties and open questions with respect to cost and energy penalty. "Three-step concept": (1) investing in state-of-the-art plants is given priority, followed by (2) increasing production efficiency, and in the last step, (3) by CCS. Interest in CCS generally corresponds to share of coal-based generation.	Involved in R&D activities (COORETEC, GEOTECHNOLOGIES, ZEP). Generally making their own investment dependent on additional public funding. Vattenfall launches oxyfuel pilot plant, RWE plans to launch an IGCC industrial scale plant by 2014.
Coal Industry (other than power producers) Deutsche Steinkohle AG DSK, Gesamtverband der Deutschen Steinkohle, Deutscher Braunkohle-Industrieverband DEBRIV (German Lignite Industry Alliance), GVSt (General Alliance of German Hard Coal), RAG (former Ruhrkohle AG, Ruhr Coal Corporation), Deutsche Steinkohle AG DSK	Passive	CCS as possible future option but open questions with regard to cost and energy penalty. Climate protection not a major issue; focus on security of supply. “Three-step concept” is partly shared. Tends to delegate the issue to electricity industry that seems more immediately affected.	Generally none; no explicit promotion.
Power Plant Industry ALSTOM, Siemens Power Generation	Ambivalent	CCS could be interesting business opportunity but many open questions. Share "three-step" concept. Commitment ultimately dependent on electricity suppliers' interest.	Involved in R&D activities (COORETEC, ZEP).
Oil & Gas Industry Shell, BP	Driver	Interested in CCS if applied in the exploitation of oil and gas fields. Various reasons: could help to comply with emissions reduction obligations, economically attractive in the case of enhanced oil and gas recovery, chances for making commercial use of existing know-how.	Heavily involved in R&D, commercial projects, organizing dialogue. Do not deal with capture from power plants – however, experience gained in storage could spill over to other sectors.
Renewable Energy Industry Bundesverband Erneuerbare Energien, BEE (Federal Alliance for Renewable Energies)	Ambivalent	CCS as possible complement to REG, no strong competition because REG are expected to become competitive but maybe competition for R&D funds.	None
Trade Unions Industriegewerkschaft Bergbau, Chemie, Energie (IGBCE) (Industrial Union for Mining, Chemicals and Energy), Vereinigte Dienstleistungsgewerkschaft, ver.di (United Services Union)	Broad spectrum, but as yet rather passive	Broad spectrum – IGBCE more positive, ver.di more negative. Do not feel very affected as of yet.	no public activities, internal discussions starting.

Actor group (and showcase examples analyzed in this study)	**General attitude**	**Basic interest / concern**	**Activities**
Research Institutes			
Regular Institutes Bundesanstalt für Geowissenschaften und Rohstoffe BGR (Federal Agency for Earth Sciences and Raw Materials), Fraunhofer Institut für System- und Innovationsforschung, ISI (Fraunhofer Institute for Systems and Innovation Research), Geoforschungszentrum Potsdam,GFZ (National Research Centre for Geosciences)	Driver, promoter of debate	CCS as possible bridging technology, more relevant globally than in Germany, many open questions to be solved, opens interesting areas for further research.	Research activities, taking active part in research programmes and cooperative projects (e.g. GFZ Coordinator for GEOSCIENCES).
"Green" Institutes Öko-Institut (Institute for Applied Ecology), Potsdam Institut für Klimafolgenforschung PIK (Potsdam Institute for Climate Impact Research), Wuppertal Institut für Klima, Umwelt, Energie, WI (Wuppertal Institute for Climate, Environment, Energy)	Ambivalent, promoter of debate	CCS possible option for climate protection but needs careful comparison with other options and regulatory framework.	Research projects, stimulating dialogue.
Parliamentary Parties			
Christlich-Demokratische Union, CDU (Christian Democratic Union), Sozialdemokratische Partei Deutschlands, SPD (Social Democratic Party), Freie Demokratische Partei, FDP (Free Democratic Party), Bündnis 90 / Die Grünen (Green Party), Partei des Demokratischen Sozialismus, PDS (Party of Democratic Socialism)	Carefully supportive	Positions are held by specialists within CDU, SPD and Greens; no detailed positions are held by FDP and PDS. CDU tends to support it, Greens tend to be critics, SPD ambivalent. However, it is a complex issue of little public interest which does not encourage parties to much engage in it.	Partly internal and first stakeholder discussions; in declarations and programmes mostly supportive to R&D in “clean coal”
Ministries			
Bundesministerium für Wirtschaft und Technologie, BMWi (Federal Ministry of Economics and Technology, former Federal Ministry of Economics and Labour)	Driver	Support for coal, export technology.	Energy Research Program based on program (COORETEC 2003).
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMU (Ministry for the Environment, Nature Protection and Nuclear Safety)	Promoter of debate	Possibly necessary option for climate protection vs. environmental and safety risks, must be handled with care, societal debate necessary.	Funding research and dialogue project on CCS as compared to renewables (WI et al. 2004).
Bundesministerium für Bildung und Forschung BMBF (Federal Ministry of Education and Research)	Driver		Funding research on storage (GEOTECHNOLOGIES Program).
Counseling Bodies and Agencies			
Sachverständigenrat für Umweltfragen SRU (German Advisory Council on the Environment), Nachhaltigkeitsrat (German Council for Sustainable Development), Wissenschaftlicher Beirat Globale Umweltfragen WBGU (German Advisory Council on Global Change)	Ambivalent; promoter of debate	CCS may reconcile coal and climate but should be used under environmental restrictions. Necessity of public debate, interest in promoting it.	WBGU, Nachhaltigkeitsrat issued recommendation, SRU currently discussing the issue, dena organized conference

due to their specialized bureaucracy and the lesser degree of politically-motivated controversy, generally have significantly more time, knowledge and human resources at their disposal to draft policies than parliament or parliamentary parties have.

NGOs and *counselling bodies* have in common that they possess no formal decision-making power whatsoever, nor any significant funds. However, they command one powerful resource: legitimacy. NGOs and counselling bodies are heard in the public debate because they are assumed to have no economic self-interest in the issue. Industry representatives interviewed in our study are well aware of this fact, consistently articulating concern that NGOs may launch a public debate on safety or environmental issues, stifling acceptance for CCS. The case of nuclear energy is often cited as a disconcerting example.

The potential influence of counselling bodies is shown by the fact that the German Council for Sustainable Development's recommendation on coal with its support of CCS has been widely recognized and debated (Nachhaltigkeitsrat 2003). Between these actors, we can find two closer-knit networks, linked by a looser net of communication and dialogue. The first network is formed among *electricity and power plant industry*, *oil and gas industry*, mostly technology-oriented *researchers*, the *BMWI* and *BMBF*. They co-operate mainly in developing, funding and executing R&D programs and projects (like COORETEC, ZEFPP and GEOTECHNOLOGIES). *Coal mining and trading industry* is connected to this network, mainly via organizational links with electricity industry: miners and power producers are part of the same corporations and are grouped in the same umbrella organizations. The *trade union* "Industriegewerkschaft Bergbau, Chemie, Energie" (IGBCE) also comprises sectors. Moreover, coal industry is also becoming engaged within the GEOTECHNOLOGIES Program.

The second network is formed by the *environmental NGOs, BMU*, *the renewable energy lobby*, and another part of the *scientific community*, mostly focusing on a socio-political, eco-

nomic, and/or socio-ecological approach. The network is mainly held together by information and consultation flows.

These two networks are connected via a looser network of communication. Ministries, electricity and power plant industry, researchers and NGOs at least know each other's positions from organized communication - for example, within ZEP, in CCS workshops organized by the mineral oil industry or in the context of the BMU research project (WI et al. 2004b). Coal mining industry, political parties and trade unions have, by contrast, taken part in such forums to a lesser degree.

Two ministries, BMU and BMWi, form a kind of "hinge" between the two networks, linking them and at the same time highlighting what separates them. As parts of the same government, they are in regular dialogue and co-ordinate their activities. On the other hand, however, they compete for responsibilities and represent conflicting interests, which limits cooperation and information flows.

Parties and *consultative bodies* are currently not part of one of the closer networks (except for individual representatives). Parties are not yet very active in the issue. As for the consultative bodies, their role is to stimulate dialogue rather than to take sides in everyday politics. Figure 1 in the Annex gives a simplified[8] portrait of the actors with their respective linkages.

To sum up, it is not easy to determine who are the most influential actors. For sure, power industry is a veto player. Without its investment decisions, CCS will not come about. However, there is no single most important actor that could make CCS a reality or shape its

[8] For the sake of clarity, it contains only organizations analyzed in this report and only the most important linkages. Whenever actors are linked by different sorts of linkages, the figure shows only the strongest ones (common projects being assumed to be the strongest, followed by membership, resource flow, and information flow).

course. Rather, we find an interdependence of a number of actors, each commanding different resources and profiting from different linkages. We can discern, though, a more central set of actors made up of industry, NGOs, and ministries, from a more peripheral one made up of parties, counselling bodies, trade unions and the mining industry.

3.1.4 Public acceptance

The opinion of the (general and local) public on CCS is a white spot in the actors constellations as portrayed so far, yet it is an essential component of a successful deployment of CCS. In debates and interviews, reference is often made to the German anti nuclear power movement in the 1980s which caused substantial supplementary costs for securing building sites, delays in construction times, and sometimes even succeeded in completely preventing the construction of power stations.

Unfortunately, very little information about public acceptance of – or opposition to – CCS is available to date. Only a handful international studies have been conducted on public perceptions and acceptability (see Coninck et al. 2006, Curry 2004, Curry et al. 2005, IEA 2005 and Peteves et al. 2005 for a comprehensive discussion), none of them on Germany. Most studies show very low levels of recognition of technology and related issues.

Major reasons found for this for this are the early stage of technology development, combined with a missing awareness of the underlying reason or the need for deploying it (global warming). In consequence, both the technology itself and the threat it is meant to combat seem remote and abstract. Shackley et al. 2004 argue that the public does not have well formed opinions on issues which are not of immediate salience or relevance to their everyday life and livelihood, a thesis that seems to apply to carbon storage. Opinions and perceptions on such "remote" issues are shaped by the media and other marketing efforts of stakeholders. Very few reports on CCS or clean coal technologies were launched in the media so far, although

the picture is slightly changing since the energy summit called in by the German chancellor on April 3, 2006. Just a few days beforehand, RWE announced to the public its plans to build "the first CO_2 free power station". Subsequently, newspapers run reports on the technology and its prospects, all of them, however, pointing to its early stage of deployment.

Curry (2004; Curry et al. 2005) argues that public outreach activities will have to address global warming and the resulting need for CCS, if CCS is to be appraised positively by a broad public, in particular the local public at construction or storage sites. So far, such activities have been rather limited. However, an increasing momentum can be stated, with a growing number of activities and publications on both sides, the critical NGO and the proponents. Surveys and focus group studies on public attitudes and concerns are conducted, and organizations like the Carbon Sequestration Leadership Forum line up to "promote awareness and champion legal, regulatory, financial, and institutional environments conducive to such technologies". On EU, national and international levels, tasks forces and meetings are formed with the objective to meet with all stakeholders including NGOs, and to develop "road maps" which include broad public outreach strategies. NGOs on the other hand are now distributing their new position papers, their major concern being that CCS may be seen as a solution which would allow the continued the use of fossil fuels as long as they are available (IEA 2004:189).

At this stage, some first ideas about the public perception of CCS may be derived from existing studies and position papers. Generally, two types of opposition to new technologies could be expected to emerge: First, opposition from stakeholders preferring other mitigation measures to CCS, and secondly, local opposition to specific projects and sites, notably storage (IEA 2004). While the first type of opposition to CCS (some NGO, some representatives of non-fossil energies) is already about to form up, the broad and the local public are not yet involved in the discourse. In a survey in two UK cities, conducted by Shackley et al. 2004, the

public turns out to be is uninformed and unsure about CCS. The initial reaction is skeptical, and after some information given to the participants, they "slightly" support it, compared to clear support, e.g., for solar and wind power. Positive features attributed to CCS include the expectation that it "buys time for other solutions" and that it helps to mitigate climate change. However, there are fears about leakage and possible damage to ecosystems . There is a perception that CCS is not yet being tested enough.

It is difficult to predict future public reaction. Experience from nuclear energy cannot be easily transferred since nuclear energy imposes other risks than carbon storage. A few lessons can be drawn from experience and the few studies, and the current and planned activities of CCS proponents with respect to public acceptance reflect these insights. In particular, public acceptance and confidence are considered to presuppose an open and transparent discussion of the positive aspects of CCS, but also of its risks and the related uncertainty. Also, a proper site selection with public involvement (stakeholder processes) is believed to reduce public opposition. Furthermore, monitoring, verification and liability issues are considered to need credible treatment, in particular regarding leakage. Similar (and a few more) points are also being raised by NGOs involved in the debate.

All in all, the public (together with the NGOs) is likely to respond with watchfulness to CCS (Hawkins 2001). If CCS is communicated as a "magic bullet", allowing policymakers to abandon all activities to foster efficiency and renewable energy, then the environmental community is likely to dissent, and local opposition to designated sites for CO_2 storage can be expected to boost.

3.2 Issues of the Debate and Potentials for Consensus

In this section, we summarize the opinions expressed by our interviewees and written documents, sketching the main issues of debate and areas of agreement and dissent.

General attitude. One interesting finding is that there is a considerable degree of consensus on many topics across actors. Most remarkably, there is little fierce opposition towards CCS – though little enthusiastic support, either. The technology seems to promise interesting options for climate protection but a number of uncertainties and risks remain. All sides agree, therefore, that it requires further scientific exploration and public discussion and all are willing to engage in such dialogue. It is also agreed upon that ocean storage is undesirable and that depleted oil and gas fields and saline aquifers are the most promising storage sites. CCS is furthermore conceived as an international issue that cannot, and should not, be decided on a national level. Future worldwide energy demand, the needs of newly industrializing countries, export options, foreign storage potential and international climate regimes will influence CCS and the development of coal.

Future electricity system. There is also moderate agreement on some *basic features of a future energy system* and on the role of coal and CCS within it. First, actors acknowledge in principle that fossil fuels (and specifically coal) will continue to be important for some decades – but that coal with CCS is only a temporary solution. The exact amount and time span of coal use is, of course, much debated (the latter ranging from 30 to 100 years), as is the nature of the future energy system. Environmental NGOs tend to adopt a wider time horizon, discussing energy futures up to the year 2050 to 2100. Industry, coal organizations and BMWI (with few exceptions) prefer to restrict their goals and visions to a shorter term, pointing out that every statement concerning time beyond about 2030 would be highly speculative. If conceived at all, the future system is mostly said to be based on supply and demand side efficiency, decentral renewable energies and combined heat and power generation. Some actors also expect fuel cells, large (off-shore) wind power, hydrogen, large-scale imported renewables and/or nuclear fusion.

Secondly, actors also agree that CCS is no "magic bullet" that will solve the climate issue without further changes in the energy system. Coal-based generation with CCS will be combined with gas-based generation and renewable energies. However, opinions differ wildly as to what the contribution of each of these options may be and to what extent they compete. Actors from coal industry tend to view gas as their main competitor. They see renewable energies as a complement but not a danger, since they do not expect significant base load capacity covered by renewables in the nearer future. For the same reason, electricity industry and the BMWI argue that coal with CCS might “fill the gap” left by renewables.

Environmentalists and renewable energy lobbyists are ambivalent on the matter. On the one hand, they are confident that cost reductions in renewable energies will make them competitive with coal and CCS. On the other hand, they fear that CCS might deduct funds from R&D on renewables and that it could be an excuse for investment in large centralized power plants which cement supply structures unconducive to energy saving, decentralized renewable energies and CHP.

Problems and risks. The energy penalty is the one pressing issue perceived by all actors. It affects resource availability, drives up prices and increases the environmental burden of resource extraction. Also, actors agree that the technical feasibility of storage needs to be proven. Besides, environmentalists point to issues of storage safety, long-term CO_2 mitigation and possible impacts on ecosystems, while electricity and power plant industry are concerned about cost and public acceptance.

Policy framework. All actors underline the necessity of a stable long-term energy policy in order to provide security of investment. Electricity and plant industry does not reject climate policy outright but rather demands climate protection goals to be predictable and internationally harmonized in order to prevent market distortion. A predictable and high CO_2 price is

often cited as necessary for making CCS competitive with conventional fossil power plants. On the other hand, a high CO_2 price tends to favour gas and renewable energies over coal, which worries coal industry. These issues point to the relevance of future international climate policy and the development of the EU emissions trading system for the future of CCS.

Furthermore, CCS needs a simple and conducive framework with respect to licensing procedures, environmental and safety standards, regulation of international cooperation and liability rules in case of accidents. It seems likely that industry accepts rather ambitious safety standards because they are concerned about public acceptance. Many actors point to the necessity of regulating these issues but very few detailed concepts have been worked out so far. We expect that, as the devil is in the details, concrete regulation of those issues will be a major source of conflict.

With respect to funding, there is little consensus emerging. All interview partners view massive R&D funding for a broad array of energy and climate technologies as necessary. Apart from that, however, there is little consensus – debate starting with the question of what a "broad array" exactly means, to what degree it should include CCS and which options should be privileged. Coal mining industry and electricity suppliers call for massive R&D funding in order to cushion risks and uncertainties. By contrast, environmentalists, Green party members and renewables proponents claim that carbon *capture* research should be financed by industry. Still, some acknowledge that *storage* research should be a public issue in order to ensure high safety standards. In any case, (as advisory bodies also agree), CCS programs should not crowd out research in renewable energies and energy efficiency, nor be used as a rationale for delaying adoption of policies to achieve near-term reductions in carbon emissions. Scientists, the Government and Social Democratic Party members point to the necessity of a calculable long-term framework for R&D with clear targets and an evaluation. Research on storage is, in their opinion, particularly relevant.

CCS and future coal use. There is no consensus on whether CCS will improve the chances of coal use in a future energy system or not. Perceptions run across established actor coalitions, ranging from "it is rather a risk" via "it has no influence at all" to "it presents a huge chance". One reason for the differences are differing perceptions of climate issues and of their relevance in public opinion. If climate issues are acknowledged and/or seen as a relevant topic in public opinion, actors feel that CCS might be beneficial for future coal use: it promises to reconcile coal use and climate protection and thus improve acceptance for coal.

If, in contrast, actors focus on topics like security of supply and energy prices (and/or see energy policy and the public debate as dominated by these issues), they will expect coal to be necessary and accepted to a great extent anyway. In this case, CCS would provide no additional benefit. In short, what makes it difficult to judge the effect of CCS on the future of coal is the fact that it may increase acceptance on the one hand, while it raises cost and lowers profitability on the other hand. It is hard to balance the two countervailing effects, especially in the face of uncertainty of cost development.

4.3 Changes in Influence Patterns?

Does the debate on CCS affect actor resources and linkages and thus change influence patterns of actors in coal policy? We contend that CCS creates ambivalences and uncertainties which partly cause traditional coalitions to loosen. The many open questions make actors more receptive to arguments and information. Many feel that they are in need of such information and therefore try to build contacts and stimulate constructive dialogue. The ambivalent effect on coal (increasing legitimacy but also cost) creates differing opinions which can cause ruptures within the industry-coal-electricity coalition. Another interest divergence is between electricity suppliers with high and low shares of coal.

The same is true, however, for environmentalists. Positions are already diversifying, and the debate has not yet reached the broad member base of environmental NGOs. Some actors expect that members may not share the reluctant interest with which CCS is met in expert circles but may be much more opposed, so that serious controversies could result.

Thus, CCS weakens traditional ties on all sides and also provides all sides with new channels of information. It is not yet clear who will profit from this situation. However, this may lead to more realistic and consensual policy options in the long run, as described in the next section.

4 Discussion: CCS and the Future of Coal in Germany

Our paper assessed the setting of actors with regard to a future deployment of CCS in Germany. We looked at the interests, activities and general attitudes of actors involved in this upcoming debate. In the following, we will present our conclusions as to the expected future of coal and CCS and close with a summary of preconditions for a sustainable transition of the electricity system – be it with or without CCS.

4.1 The Potential Future of Coal and CCS in Germany

It is likely that **CCS will come**, most probably as an integrated process (no retrofit). Indicators are the increasing R&D activities – both nationally and internationally, by governments and by industry – and the fact that there are only few principally opposed actors. Activities to develop the necessary regulatory framework are already underway on an international level, although they are not so much recognized in the German debate. For example, the IPCC is currently issuing new guidelines for including CCS into national greenhouse gas inventories (Eggleston 2006, IPCC 2006). Also, in an October 2006 workshop, the International Energy Agency has done intensive work on legal aspects (IEA 2006). As recommended by the Work-

ing Group on CCS under the Second European Climate Change Programme (ECCP II), the European Commission is planning to issue a Communication on CCS for the second half of 2007 and to develop draft legislation for the topics of risk, liability, legal barriers and incentives (Dimas 2006b, Lefevre 2006, Working Group on CCS 2006).

However, even if CCS will come in Germany, it remains to be seen which share it will take on in the future electricity generation mix.

There is no single most important actor operating as **driver** of CCS. Rather, we find an interdependence of a number of actors, each commanding different resources and benefiting from different linkages. We can discern, though, a more central set of actors (made up of electricity, power plant, and oil and gas industry, NGOs, and ministries), from a more peripheral one (made up of parties, counselling bodies, trade unions and the mining industry).

The debate on CCS and the resulting movement in the actor constellation opens up space for the concept of fossil fuels – including coal – as transitional fuels. Environmentalists tend to acknowledge that fossils are necessary for a transition period. Coal proponents do not openly discuss the fact (but they do not deny it anymore either) that this transition period will end one day. CCS could thus help to reconcile fossil fuel use and climate protection during that transition period, provided that the numerous technical, economic, ecological and safety issues are resolved.

CCS may thus **prolong** the dominance of the current coal-to-electricity path to some 100 years instead of about 40 years as maintained by environmentalists. As carbon separation is only viable for high emission points, the current structure of centralized coal-fired power plants will be partly conserved. Not all investment is likely to flow into such plants, though – rather, a mix of central and decentralized options based on different fuels is likely to result. Such a trajectory seems reasonable as long as it is compatible with climate protection and

other sustainability demands and as long as the transition period is used to develop alternatives to the fossil system that may ultimately result in a more "renewable" future.

Timing is another important issue. With their "three-step" concept, industry gives priority to the installation of current state-of-the-art plants, so that a number of conventional coal plants will have been installed by 2020, thus reducing the future CCS potential. Hence, coal has a future in Germany even without deployment of CCS. However, contrary to public perceptions, there is no “window of opportunity” that strictly closes in 2020, the year often mentioned as the end of a period of necessary massive reinvestment in Germany. It is rather a continuous replacement process that still allows for a step-by-step implementation of CCS after 2020, followed by a slow but steady decommissioning of CCS plants towards the depletion of CO_2 storage capacities.

Aside from this, CCS is relevant not only for Germany. In fact, emerging economies like China and India (and other developing countries) have even more potential as addressees for the deployment of CCS (Unruh 2006; Watson 2005). Stern (2006: 368) also points out that “…CCS is a technology expected to deliver a significant portion of the emission reductions. The forecast growth in emissions from coal, especially in China and India, means CCS technology has particular importance. Failure to develop viable CCS technology, while traditional fossil fuel generation is deployed across the globe, risks locking-in a high emissions trajectory.” For Germany, this opens up new perspectives for power plant industry – a new export market can be developed. To this end, technology development and implementation in Germany is an important step. However, whether CCS will take off in emerging economies ultimately depends on the climate regime.

4.2 Conclusions for A Future Deployment of CCS

In this last section, we draw some conclusions for the future development of CCS in the context of the total electricity system. We base them both on the potential role of CCS as a bridging technology and on the assessment of political actors' acceptance.

CCS should not be considered a magic bullet but as one option within a broad portfolio of climate protection measures, competing for their implementation. Such a broad portfolio allows to choose those options with lowest CO_2 mitigation cost. CCS can assume a specific role within that portfolio as a bridging technology during a transition from a carbon-based towards a carbon-free electricity system. Although there is widespread consensus on this idea, none of the actors portrayed here has developed scenarios for such transition so far. And none of them has an incentive to do so as long as they do not expect a stringent climate policy framework to enter into force. For environmentalists, doing so would mean to explicitly accept a prolongation of the carbon period (or even a carbon lock-in), which they are reluctant to do. Counselling bodies and the scientific community could be appropriate actors to solve this task but have not yet dealt with the issue in detail.

Therefore, a clear and reliable policy framework needs to be in place to develop the portfolio of technologies and allow for a transition towards a low-carbon or even carbon-free future. Such a framework consists of four core elements.

First and foremost, power generation cost must reflect environmental cost. For this, clear and stringent climate targets are needed, so that CO_2 has a price and CO_2 emissions become a relevant cost factor in electricity generation. This stimulates the development of efficiency and renewable technologies, and also of CCS. All actors accept or support long-term climate goals and policies, as long as they are stable, predictable and internationally harmonized. Policymakers should hence build on such consensus and offer a reliable framework.

Secondly, a precondition for CCS is a well-developed regulatory and institutional system, in order to ensure a secure operation and monitoring of storage sites, to prevent leakage and to regulate liability issues. Secure operation needs to be made a precondition for CCS implementation.

Thirdly, public funding for CCS is needed to explore its potential. Here, policymakers can build on the consensus that a broad array of energy sources should be supported, and CCS should not crowd out research on renewable energies or energy efficiency. A sensible decision would be to focus public involvement on basic research and on issues of public interest, like storage safety, while leaving commercial development of capture technologies as a task for industry R & D. An appropriate funding policy must also ensure the development of technologies that are not yet economic today, but may be needed in the future to combat climate change or replace scarce and environmentally problematic fossil fuels.

Fourthly, as public acceptance is an important aspect of a future deployment of CCS, any strategy to implement CCS needs active and open public outreach activities, combined with a well-developed regulatory framework.

To summarise, CCS is an incremental innovation that has a certain potential to smoothen a transition towards a less carbon-intensive energy future – provided that the related uncertainties are resolved, in particular with respect to leakage and liability. The actor constellation in Germany currently opens up such possible trajectories for using CCS as one bridging technology among others towards a more sustainable electricity system.

This paper could only touch upon a number of issues that deserve to be treated in more detail in future research. In particular, likely investment decisions up to 2020 and their dependence on climate and energy policy are major issues to be investigated in more depth. A deeper analysis of actor constellations might shed more light on the question of who actually profits

from the CCS debate and who is likely to gain more influence. The embedding of national trajectories in the international environment also deserves further attention. Ultimately, a scenario analysis for the transition of the electricity system towards a renewable energy future, which includes CCS and CCS combined with biomass as a fuel (net sink) and gives special attention to the issue of the appropriate timing of investment, is required.

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Annex 1: List of Actors and Data Sources

Organization	Data Sources		
	Written Material	**Interview**	**Conference Presentation by Actor**
Environmental organizations			
Germanwatch	X	x	x
Climate Action Network (CAN)		x	
World Wide Fund for Nature (WWF)	X	x	
Greenpeace	X	x	x
BUND	X	x	
NABU		x	
Electricity Industry (power producers)			
Verband der Großkraftwerksbetreiber, VGB Power Tech (Alliance of Large Scale Power Plant Operators)	X	could not be realized	x
RWE Power AG	X	x	x
Energie Baden-Württemberg, EnBW		x	
E.on	X	x	
Vattenfall	X	x	
SteAG	X	x	
Coal Industry (other than power producers)			
Gesamtverband der Deutschen Steinkohle, GVSt (General Alliance of German Hard Coal)	X	x	
Deutscher Braunkohle-Industrieverband DEBRIV (German Lignite Industry Alliance)	X	could not be realized	
RAG (formerly Ruhrkohle AG, Ruhr Coal Corporation)	Represented by its daughter corporations SteAG and DSK		
Deutsche Steinkohle AG DSK	X	short phone call	
Power Plant Industry			
ALSTOM		X	x
Siemens Power Generation	X	X	x
Oil & Gas Industry			
Shell			x
BP			x
Renewable Energy Industry			
Bundesverband Erneuerbare Energien, BEE (Federal Alliance for Renewable Energies)		X	x
Trade Unions			
Industriegewerkschaft Bergbau, Chemie, Energie (IGBCE) (Industrial Union for Mining, Chemicals and Energy)		X	
Vereinigte Dienstleistungsgewerkschaft, ver.di (United Services Union)		X	

Research Institutes			
"Green" Institutes			
Wuppertal Institut für Klima, Umwelt, Energie, WI (Wuppertal Institute for Climate, Environment, Energy)			x
Potsdam Institut für Klimafolgenforschung PIK (Potsdam Institute for Climate Impact Research)		x	
Öko-Institut (Institute for Applied Ecology)		x	
Regular Institutes			
Fraunhofer Institut für System- und Innovationsforschung, ISI (Fraunhofer Institute for Systems and Innovation Research)			x
Bundesanstalt für Geowissenschaften und Rohstoffe, BGR (Federal Agency for Earth Sciences and Raw Materials)	X	x	
Geoforschungszentrum Potsdam, GFZ (National Research Centre for Geosciences)		Short e-Mail contact	
Parliamentary Parties			
Christlich-Demokratische Union, CDU (Christian Democratic Union)	X	x	
Sozialdemokratische Partie Deutschlands, SPD (Social Democratic Party)	X	x	
Freie Demokratische Partei, FDP (Free Democratic Party)	X		
Bündnis 90 / Die Grünen (Green Party)	X	two	
Partei des Demokratischen Sozialismus, PDS (Party of Democratic Socialism)	X		
Ministries			
Bundesministerium für Wirtschaft und Arbeit, BMWA (Ministry of Economics and Labour)	X	x	
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMU (Ministry for the Environment, Nature Protection and Nuclear Safety)	X	two	
Counseling Bodies and Agencies			
Wissenschaftlicher Beirat Globale Umweltfragen, WBGU (German Advisory Council on Global Change)	X		
Nachhaltigkeitsrat (German Council for Sustainable Development)	X	x	
Rat der Sachverständigen für Umweltfragen, SRU (German Advisory Council on the Environment)	X		
Deutsche Energieagentur, dena (German Energy Agency)		x	

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Figure 1:

Actor network in the coal / CCS system