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CCS for Germany: policy, R&D and demonstration activities

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Abstract

While the share of renewables has been growing rapidly since the 1990s, at present electricity generation in Germany is still based on coal and nuclear energy, with nuclear power and lignite covering almost the whole base load electricity generation, and hard coal serving as the main energy carrier for medium-load generation. However, both coal and nuclear energy are facing major challenges. The future of coal in Germany is uncertain against the background of strong climate policy regulations and issues of public acceptance. In line with current legislation, nuclear power is being phased out. In its strategy for CO_2 emissions reduction, the German government has identified the carbon capture and storage (CCS) technologies as one of the options. Major government papers highlight the importance of further research and development (R&D) in the field of CCS technologies. German industry supports R&D activities on CCS by participating in the work of public-private partnerships (PPP), e.g. the COORETEC initiative, the GEOTECHNOLOGIEN programme, as well as by implementing CCS demonstration projects. In view of the difficulties coal has been facing with regard to public acceptance in Germany, the public acceptance of CCS technologies is recognised as an important precondition for their large-scale deployment. Thus, research on public acceptance of CCS is one of the priorities accompanying R&D on these technologies. Besides the strategy of fostering national R&D activities on CCS, Germany is actively participating in international networks and organisations dealing with the CCS issues.

Keywords: CCS; Germany; R&D; demonstration; policy

1. Introduction

The paper presents a snapshot of German R&D and demonstration activities in the field of CCS technologies with the focus on the policy aspect. The background to the work is an ongoing reflection and analysis of different aspects of climate protection strategies within the framework of system analysis provided by Forschungszentrum Jülich GmbH. The paper has an informative character. The opinions expressed in the paper are those of the authors and not of the institutions.

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2. Electricity generation in Germany: a fragile backbone?

Although the shares of natural gas, wind and hydropower have grown rapidly since the beginning of the 1990s, electricity generation in Germany is still based mainly on coal and nuclear energy. The demand for electricity has steadily risen from 539.6 TWh in 1991 to 617.6 TWh in 2007 [1]. For this period of time, the annual growth rate amounts to approximately 1%. The share of traded electricity accounted for less than 10 % of total electricity demand (2006). In 2007 exports of electricity exceeded the imports by 19.0 TWh [ibid]. This trend also remains valid for 2007.

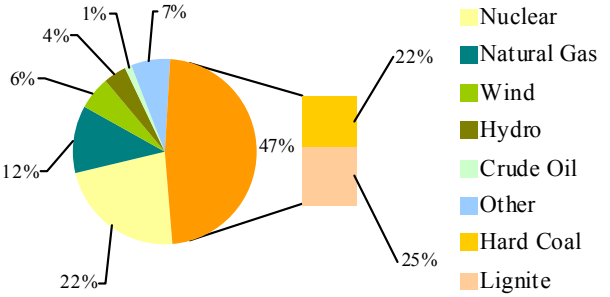

Fig.1: Total gross electricity generation in Germany (%, 2007)
Source of data: German Federal Ministry of Economics and Technology (BMWi), 2008

The importance of hard coal, lignite, and nuclear energy for German electricity generation is highlighted by their outstanding position with regard to base and medium load generation. Nuclear power and lignite cover almost the whole base load electricity generation, whereas hard coal is the main energy carrier for medium load generation. In contrast, natural gas is mainly used to provide peak load electricity generation. However, it is taking an increasing share of medium load generation.

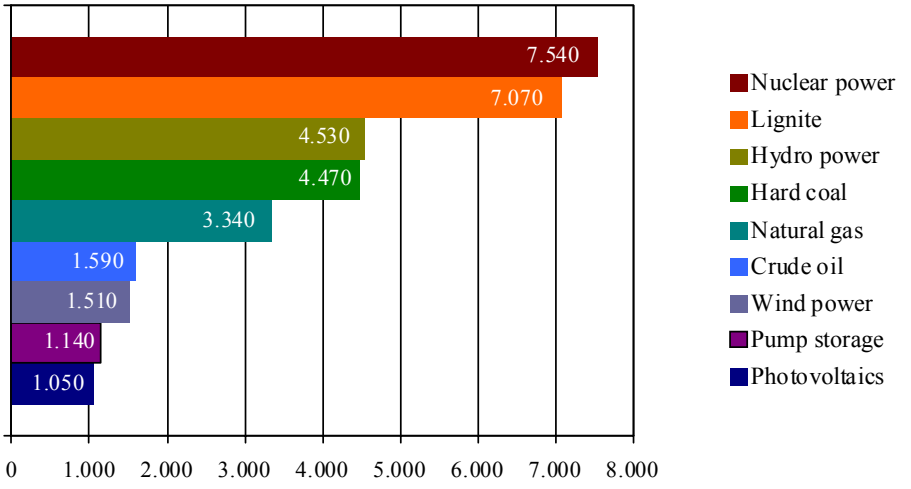

Fig.2: Average utilisation hours of power plants (example Germany, year 2005)
Source of data: Statistisches Bundesamt, Wiesbaden; Verband der Elektrizitätswirtschaft, Berlin

Coal is currently struggling with issues of public acceptance and nuclear energy is being phased out. These developments represent a challenge for the future of a stable electricity supply and influence the role of carbon capture and storage technologies in the German coal-to-electricity system.

The debate on challenges facing the future security of supply and climate change has resulted in a range of policy targets and measures which have been expressed in such government papers as *Key Elements of an Integrated Energy and Climate Programme*. This includes an increase in the share of power produced by renewable energies to 25-30 % by 2020; a doubling of the proportion of power generated from combined heat and power to approximately 25 % by 2020 (base year 1990); and an increase of energy efficiency in different sectors. Beyond the goal of reducing CO_2 emissions by 21% (base year 1990) in the period from 1990 to 2012, which is likely to be met, the climate protection goals accepted by Germany aim at reducing CO_2 emissions by up to 40% by 2020 (base year 1990, dependent on EU 30% target).

3. German R&D activities towards CCS

Against the background of uncertainties connected with the use of nuclear power for base load electricity generation, other energy options – including coal – are gaining importance. In this context, CCS technologies present an attractive option allowing the continued use of coal in accordance with the guidelines of climate protection. In addition, CCS technologies could also be a solution to the lack of public acceptance for coal in Germany.

Besides efforts aimed at increasing both energy efficiency and the share of renewables, the German government is also pursuing the strategy of reducing CO_2 emissions from the use of fossil fuels. The important component of this strategy is the industrial deployment of new low-CO_2 power plant technologies. The German government has therefore identified CCS technologies as a possible option within the framework of CO_2 emissions reduction strategies.

Different aspects of the development of CCS technologies are distributed among different ministries within the German government. For instance, research on storage is the responsibility of the Federal Ministry of Education and Research (BMBF) within the framework of its GEOTECHNOLOGIEN programme, while technological and industrial aspects of CCS related to the capture of CO_2 in the conversion process and the transportation of CO_2 are covered by the Federal Ministry of Economics and Technology (BMWi) within the COORETEC initiative, whereas the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) deals with the environmental issues of CCS. Also, together with BMWi, BMU works on regulatory and legal issues.

Major government papers highlight the purpose of further R&D on CCS technologies.

In the 5th Energy Research Programme - *Innovation and New Energy Technologies* (2005), the German Federal Government provides a strategic outline of its energy research. The main topics of the programme include R&D funding in the following sectors - energy efficiency, renewable energies, fuel cells and hydrogen, energy-optimised construction, and fossil fuel power plants with CCS. The programme operates between 2005 and 2008 with budget funding of € 1.7 billion.

Key Elements of an Integrated Energy and Climate Programme (2007) is a package of targets and measures drawn up by the German government and several ministries to comply with the parameters for an integrated European climate and energy policy introduced by the European Council. This programme regards the CCS technologies as one of the CO_2-emission reduction options. It has set the goal of examining the technical, environmental and economic feasibility of CCS technologies. Development of a suitable legal framework for CCS as well as the construction of demonstration power plants in Germany are among the measures needed to be taken in order to achieve this goal.

The High-Tech Strategy for Germany introduced in 2006 as well as *The High-Tech Strategy on Climate Change Protection* introduced in 2007 address CCS technologies as a climate change mitigation option and emphasise the importance of the COORETEC initiative driven by the BMWi.

The legal framework for CO_2 storage is still under development. The German government aims at a harmonised European understanding of this topic. On 23 January 2008, the European Commission presented a proposal for a Directive on the legal framework design for CCS. It is expected that the European Parliament will come to a decision on the CCS directive toward the end of 2008. The progress of the European legislation as well as the design of the future legal framework could delay industrial projects requiring the storage of CO_2.

3.1. R&D activities in public-private partnerships

R&D efforts on CCS technologies, as well as the implementation of demonstration projects, are being carried out within the framework of public-private partnerships (PPP). PPP is a widely used instrument for pooling public and private activities in Germany. Especially in the field of power plant technologies PPP have a long history of successful activities in applied research. The COORETEC initiative and the GEOTECHNOLOGIEN programme are examples of PPPs in R&D activities on CCS.

The COORETEC concept is directed towards two focal areas: improving the efficiency of existing power plant technologies and exploring the potential of new technological options offered by CCS technologies [2]. The initiative was started in 2002, and the first projects began in 2004. The R&D funding provided by BMWi amounts to € 93.3 million for the period from January 2004 to April 2008 [3]. During this period of time, 200 projects were approved, with industry accounting for 53% of the approved projects, and universities and research labs for 28% and 19% respectively. Industry participates in the COORETEC initiative by co-financing projects.

The work of the COORETEC initiative is steered by the COORETEC Advisory Council and is organised in 5 working groups (WG): Natural Gas Combined Cycle Power Plants (WG 1), Steam Power Plant and Post-Combustion Capture (WG 2), IGCC with Pre-Combustion Capture (WG 3), Oxyfuel (WG 4), and CO_2 Storage (WG 5). The activities of the COORETEC initiative are strongly oriented to applied research. Industry is not only involved in the implementation of the projects but also contributes to steering the work of the COORETEC initiative. One of the results of the cooperation within the framework of COORETEC initiative is the major demonstration projects described below (see section: “Demonstration projects”).

The following figure presents the COORETEC roadmap as it was adopted in 2002. It is a sign of the rapid development in CCS technologies that certain milestones set in this roadmap will probably be realised earlier than expected in 2002, e.g. the Oxyfuel and IGCC demo constructions.

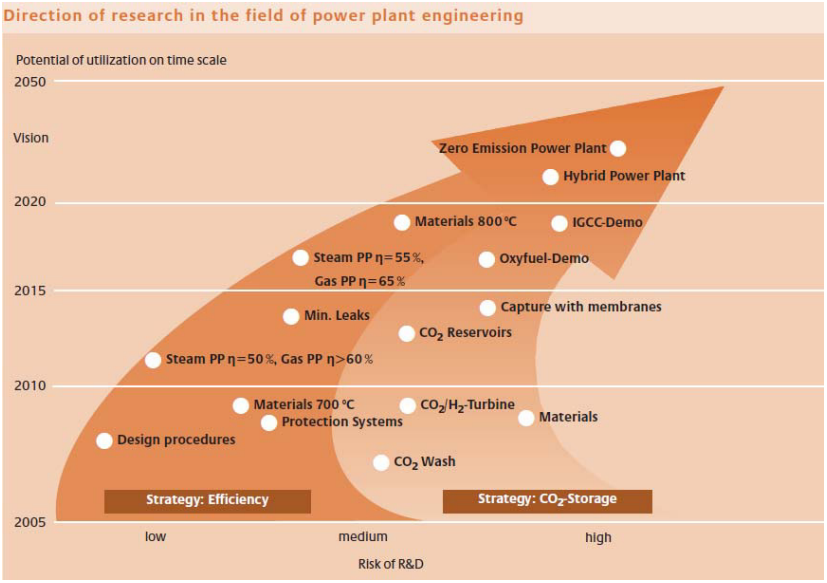

Fig.3: COORETEC Roadmap
Source: New Energy Technologies - The 5th Energy Research Programme of the Federal Government [4]

The GEOTECHNOLOGIEN programme has traditionally been more oriented to basic research. It does not have a long tradition of PPP and until recently has mainly been driven by science. One of the foci in the GEOTECHNOLOGIEN programme aims at analysing the potential of geological formations for storing CO_2 [5]. The GEOTECHNOLOGIEN programme was started in 2000, and the first projects on CO_2 storage were introduced in 2005. The total budget spent in the first funding phase (2005-2008) on CO_2 storage projects amounts to € 6.9 million, of which € 5.7 million was funded by BMBF and € 1.2 million by industry [3]. The first funding phase resulted in 9 interdisciplinary joint projects between academia and industry, and 12 research institutions cooperated with 13 companies. The main research objectives were directed towards options for long-term, safe CO_2 storage in Germany as well as the development of new technologies for long-term monitoring activities. The second funding phase (2008-2011) comprises a total volume of € 19.6 million, of which BMBF provides € 13 million and industry € 6.6 million. For the current funding phase, the main objectives include the extension of basic research on storage and surveillance technologies, complementing the pilot projects.

4. Demonstration projects

Not all of the technologies and components needed for the deployment of clean fossil fuel power generation systems including CCS can be seen as state of the art today. Therefore, the system-wide implementation of CCS technologies depends on large-scale demonstrations to prove their technical and economical feasibility. The following projects demonstrating CCS technologies have been recently announced by German industry.

Net efficiency increase:

Every increase in efficiency prevents the production of some CO_2 and thus reduces the amount of CO_2 which needs to be captured and stored. Highly efficient energy conversion technologies therefore represent the key to the economic competitiveness of CCS plants. Several projects are in progress on improving the efficiency of the conversion process.

Siemens is making a full-scale test of its latest most advanced gas turbine at an E.On power plant site at Irsching in Bavaria. A natural-gas-fired combined cycle power plant on the basis of this gas turbine will provide a net efficiency of above 60% and the net electricity output will amount to 530 MWe. In this way, the magic limit of 60% efficiency will be exceeded for the first time.

A European industrial consortium supported by the European Commission and coordinated by the German VGB has built and is operating the COMTES 700 test facility at one unit of the E.ON power plant site at Scholven (North Rhine-Westphalia, Germany) to demonstrate the operational safety and reliability of a power plant at a steam temperature of 700°C and above. The goal is to demonstrate the integrity of the facility under real operation conditions. Another test loop has been introduced into a coal-fired steam boiler in Mannheim. this will operate at 725°C.

E.On announced construction of the first coal-fired power plant with a net efficiency of over 50% and a capacity of about 550 MWe. This demo plant will operate at a steam temperature of 700°C and pressure of 350 bar. The start of operation at this facility located in Wilhelmshaven is planned for 2014. E.ON is investing around € 1 billion in the project.

Pre-combustion:

RWE Power is developing and building a zero-CO_2 450 MW coal-fired power plant (net efficiency near to 40%) based on IGCC technology including CO_2 transport and storage. The start of operations is planned for 2014 at a site near Cologne. Priority within this project is given to the demonstration of the general feasibility and availability of the process instead of optimisation of the efficiency. However, it is envisaged that there is significant potential for further increasing efficiency with this technology.

Post-combustion:

In parallel, RWE Power will develop the technology of CO_2 scrubbing for future advanced coal-fired steam power plants and as a retrofit option for modern installations. The erection of a related pilot-scale plant has been started recently at one of the company's power plant sites in the Rhineland . It will be in operation by 2009.

Oxyfuel:

Since 2005 Vattenfall has been running a project to build a 30 MWth oxyfuel power plant. Construction was completed in 2008, the facility has been put into operation and is running in a test phase. The total budget of this project comprises approximately € 60 million. A larger power plant with oxyfuel has been announced for 2015.

Storage:

With regard to the issue of CO_2 storage, until recently work was mainly driven by science. The involvement of industry has been not as significant as in the development of CO_2 capture technologies, which evolved within the framework of traditionally strong PPP in the field of power plant technologies development. Recently, there has been growing industrial involvement in issues of CO_2 storage research. Follow-on projects and research activities on CO_2 storage in Germany are being implemented.

CO2SINK represents a project within the 6th European Framework Programme, which is funded by the European Commission, BMWi, BMBF, and industry. The goal of the project is to gain experiences with large-scale underground storage of CO_2 (onshore) at Ketzin in Brandenburg. Injection of CO_2 started in summer 2007.

Recent studies have identified storage capacities for CO_2 in saline aquifers for a range of 50 to 100 years. The locations of present power plants and suitable storages may not have an optimum fit[6]. The assessment of underground storage represents an ongoing task in Germany. Only rough estimates of the potential capacities exist

so far and vary quite strongly. These will have to be specified in more detail with respect to quality and capacity. To complete an inventory of possible CO_2 storage sites and capacities in Germany, the Federal Institute for Geosciences and Natural Resources (BGR) started a *Speicherkataster* project. This project is funded by BMWi. It started in April 2008 and will continue until March 2011.

The R&D project *CLEAN - CO_2 Large-scale EGR in the Altmark Natura -gas field* within the framework of GEOTECHNOLOGIEN aims at the development of technologies and methods for CO_2 storage and EGR. The total funding budget amounts to € 38 million, with € 15 million being contributed by BMBF and an industrial share of € 23 million. The first phase of the project runs from 2008 to 2011. 17 research institutions and companies are participating in the project.

Several projects on a smaller scale ranging from basic research in materials science to the development of components complete the picture of activities on CCS in Germany.

5. Public acceptance of CCS

The public acceptance of CCS is an important precondition for the large-scale deployment of these technologies. The issue of the public acceptance of CCS technologies may develop in a twofold manner. On the one hand, CCS can be perceived as a solution for the climate-friendly use of coal. Seen from this perspective, CCS would change the image of coal as a "climate killer" and would strengthen this pillar of German electricity generation. On the other hand, CCS itself may suffer from the negative image of coal in certain sections of the population. In this case, the large-scale deployment of CCS may be put at risk.

Research on public awareness in Germany has recently started to focus on the issue of CCS. Wuppertal Institut, Forschungzentrum Jülich (STE), Fraunhofer Institut (ISI), and BSR Sustainability GmbH carried out a joint project on the public awareness of CCS on behalf of BMWi. On the basis of the empirical results of the completed project, *Socio-economic Research on Acceptance of CCS* [7], it has been concluded that at present the majority of the public in Germany is neither for nor against CCS, because the level of awareness among the public is very low or virtually nonexistent. Thus, neutral and transparent information on CCS technologies is an important element for the further discussion of the potential of CCS as a climate change mitigation opportunity. For the process of creating knowledge among the general public, balanced information should be provided as well as an open and fair dialogue with all relevant stakeholders and social group. Particularly with regard to population groups living close to power plant sites where the construction of CCS is envisaged, it is of crucial importance to provide information and establish dialogue structures at an early stage.

However, the establishment of information flow alone is not a sufficient precondition for public acceptance. It is even more important to explore how information on CCS technologies can be communicated in order to create stable and predictable public opinion. Thus, the cooperation project within the framework of FENCO-ERA on *Public acceptance and development of public communication and outreach on CCS* aims to develop recommendations for the communication of CCS enabling the public to establish their own informed opinion. For this purpose, the project will carry out a comparative study of the communication of CCS in seven European countries: Germany, Greece, Latvia, the Netherlands, Norway, Romania and the United Kingdom. Germany acts as the project coordinator.

Moreover, conferences, workshops and publications have been initiated to improve overall knowledge on issues of public acceptance.

6. International embedding of German R&D activities

German institutions actively participate in international collaborations with regard to RD&D of CCS technologies. The International Energy Agency (IEA) devotes significant resources to exploring the potential of CCS and to promoting projects on CCS. Within the framework of IEA, the Working Party on Fossil Fuels (WPFF) advises IEA on issues related to fossil-fuel technologies and coordinates the work of the various Implementing Agreements. Among the Implementing Agreements dealing with CCS technologies, Germany has a member status in the Implementing Agreement Clean Coal Centre (CCC) as well as in the Implementing Agreement Greenhouse Gas R&D Programme (GHG R&D Programme). Whereas, CCC addresses the topic of advanced clean fossil-fired power plant technology, the GHG R&D Programme explores CCS from a holistic perspective considering all relevant issues ranging from technical through economic to political questions. The particular importance of internationally embedding German R&D activities on CCS technologies is highlighted by a decision to host the fourth IEA Conference on Clean Coal Technologies, held in association with the third International Freiberg Conference on IGCC & XtL Technologies (May 2009) in Dresden, Germany. The German Federal Ministry of Economics and Technology has agreed to be patron of the conference.

The Carbon Sequestration Leadership Forum (CSLF) is an intergovernmental international climate change initiative focused on political issues and RD&D of CCS technologies. Cooperation within CSLF reaches beyond the OECD countries and also embraces the issues of technology transfer and capacity building. CSLF activities are performed within the framework of the recognised projects. CO2SINK is one of these projects taking place in Germany and coordinated by Germany.

Germany participates in various EU activities on CCS ranging from projects in their Framework Programmes and the ERA NET FENCO up to and including the Technology Platform on Fossil Fuels. The European Technology Platform for Zero Emission Fossil Fuel Power Plants (ETP-ZEP) is an industry-driven agreement aiming at the implementation of large-scale CCS demonstration projects.

7. Conclusions

German energy policy is based on the pillars of security of supply, economic efficiency, and environmental protection. To balance these targets, Germany not only pursues the strategy of increasing both energy efficiency and the share of renewables, but also approaches CO_2-emissions reduction from the use of fossil fuels. Major governmental publications show that Germany has identified the CCS technologies as one of the options in the strategy of CO_2 emissions reduction. From the active involvement of German industry in the R&D work directed towards CCS technologies within the frame of PPP as well as from the variety of demonstration projects carried out by the German industry, it can be concluded that German industry regards CCS technologies as a viable option. The strategy of fostering R&D on all levels (national, international) and with regard to all components of the technology (CO_2 capture, CO_2 storage) can be seen as a key element of current CCS policy. While Germany is aiming at a harmonised European design of the legal framework for CO_2 storage, there is a political willingness to translate European into national legislation and, thus, to enable the timely implementation of large-scale demonstration projects requiring CO_2 storage. R&D on CCS technologies is accompanied by the study of public acceptance issues. As at present most of the public in Germany do not have any distinct opinion about CCS, there is a chance of establishing an open and fair dialogue within society.

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