Geological Storage of CO_2 in Germany –
R&D-Highlights from the national network of public/private partnership

Ludwig Stroink,

GEOTECHNOLOGIEN Coordination Office; Potsdam, Germany;

Abstract
In 2005 a portfolio of 10 research projects on CO_2-storage has been started under the umbrella of the national research programme GEOTECHNOLOGIEN. These projects - incorporating 14 universities and research institutions and 15 companies - represent the first trans-institutional platform for a broad and interdisciplinary research on this topic in Germany.

The willpower to act
According to the commitments of the Kyoto protocol the EU countries are challenged to reduce the emission of carbon dioxide (CO_2) by 8 % from 1990 levels till the period 2008-2012. For Germany this means a reduction of greenhouse gases by 21% till this period. But the government went still beyond this goal and released a national climate protection programme with a national target to reduce the anthropogenic CO_2 emissions by 40% until 2020 under the precondition that the EU reduces greenhouse gas emissions by 30%.
Germany is the most important CO_2-emitter throughout Europe with more than 800 Mio. tons of CO_2 in 2003.

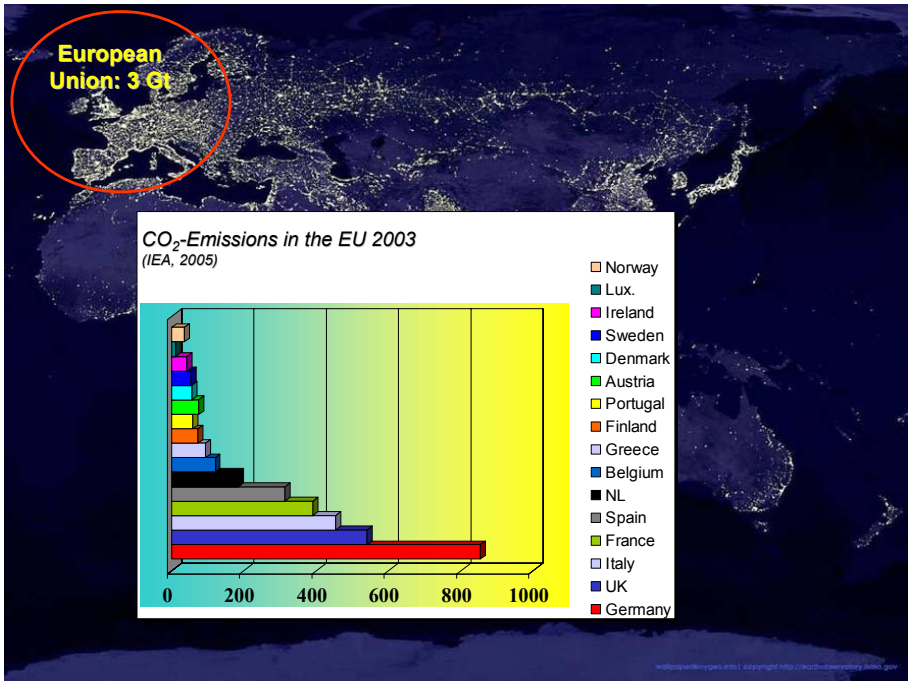

Fig. 1: CO_2-emission in Europe 2003

In the early 90´Germany was quite successful in reducing the CO_2 emissions. In the first five years after the German reunification they drop by 13% or 150 Mio. tons of CO_2. However, a considerable part of this initial progress was directly connected with the break-down of the smokestack industries (heavy industry) in former Eastern Germany and the consequences of economic restructuring. For the last 8 years the CO_2 emissions remained nearly static with a decline of only 4 %. The overwhelming part of this greenhouse gas is emitted by Power Plants (43%). Traffic follows with 19%, industry with 25 and the private sector emitted 13% of the German anthropogenic CO_2 emissions in 2004.

In the recent German energy mix coal plays a pivotal role. More than 50% of the energy supply is produced by brown- and hard coal fired power plants, 30% comes from nuclear energy, 10% from natural gas and, recently, about 3% is derived from renewable energy sources, mainly wind-power. Despite the growing

importance of renewable energy sources, it can be assumed that coal will retain its pivotal role in the German energy supply in the coming decades. However, coal can only make an important contribution to the sustainable energy industry, if the amount of CO_2 released during its combustion is minimised or does not reach the atmosphere at all. Several forecasting studies on energy policy strategy, e.g. by the German Council for Sustainable Development, prioritized among the different measures, the CO_2 capture and storage technologies as one of several options that would achieve this goal and could be a bridge in the transition from the age of fossil fuels to that of renewable energies.

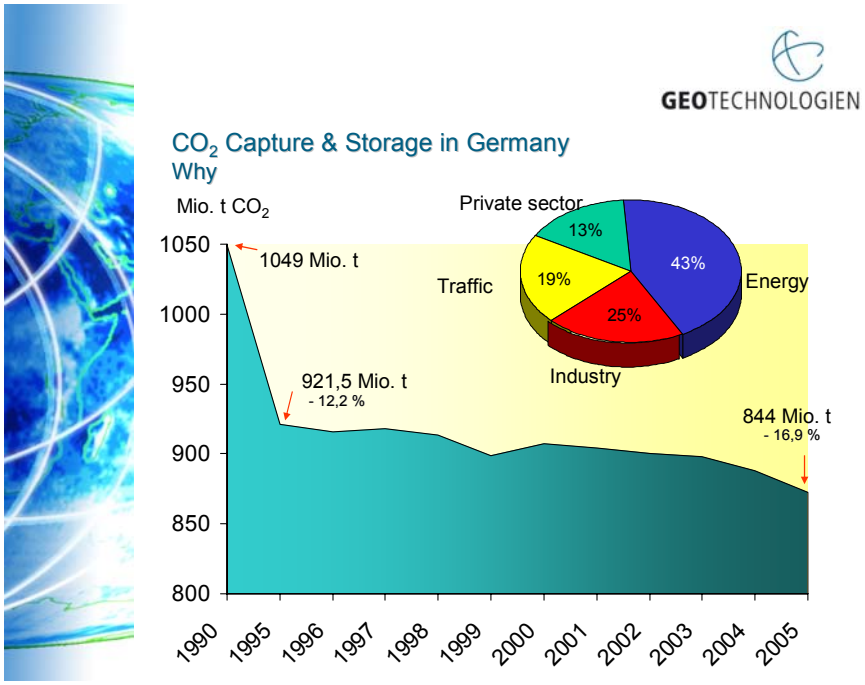

Fig. 2: Development of the energy induced CO_2-emissions in Germany (1990 – 2005) and their sectoral structure.

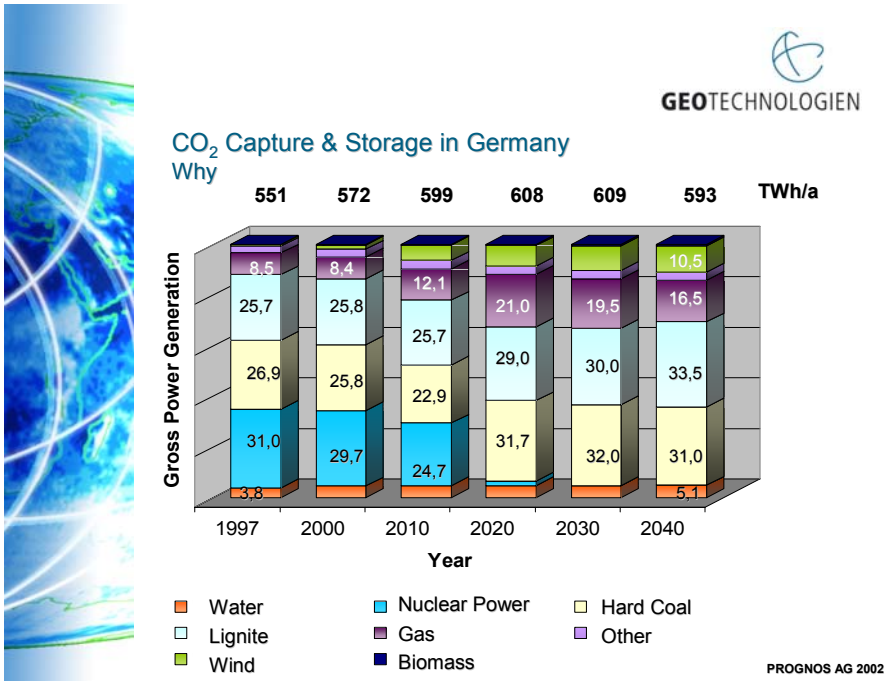

Fig.3: The energy mix in Germany.(Source: PROGNOS AG, 2002)

Germany's commitment

Therefore in summer 2005 a portfolio of 10 research projects between academia and industry has been started in the framework of the national research programme GEOTECHNOLOGIEN. They represent a key element in the organization of German research in the field of CO_2 capture and storage and are another knot in the national network that is active in both European and international projects. 6.7 Million Euro has been provided by the German Ministry for Education and Research (BMBF) for a first three year funding phase. Another 1.3 Million derive from the several enterprises, active in the joint projects between academia and industry. By this the projects are a response to the need to more effectively federate national efforts, whilst giving them better public visibility. All projects focus exclusively on technologies for geological storage. Due to its high risk, ocean storage of CO_2 is not included in the research programme; nor is capture of CO_2. The latter topic is addressed in the framework of the German COORETEC-Programme, funded by the Federal Ministry of Economics and Technology.

Overall goals of the integrated joint projects are (i) to assess the various options for geological storage of CO_2 in Germany and (ii) to provide a sound scientific basis for decision makers to evaluate the ecological and economic implications of this technology. Research activities focus on two main objectives:

- Development of technologies for a safe and permanent storage of CO_2, including their testing at the laboratory- and field scales, as well as the identification of potential storage sites in Germany.
- Development of reliable methods and technologies for a permanent monitoring of selected storage sites.

Key topics are:

- Evaluation of potential storage sites and storage technologies
- Baseline characterisation (e.g. geology, reservoir/caprock features)
- Storage operation (injection technologies, EOR/EGR potentials)
- Development/implementation of reliable short- and long-term monitoring techniques
- Development and evaluation of strategies for the elimination, transformation and permanent immobilisation of CO_2

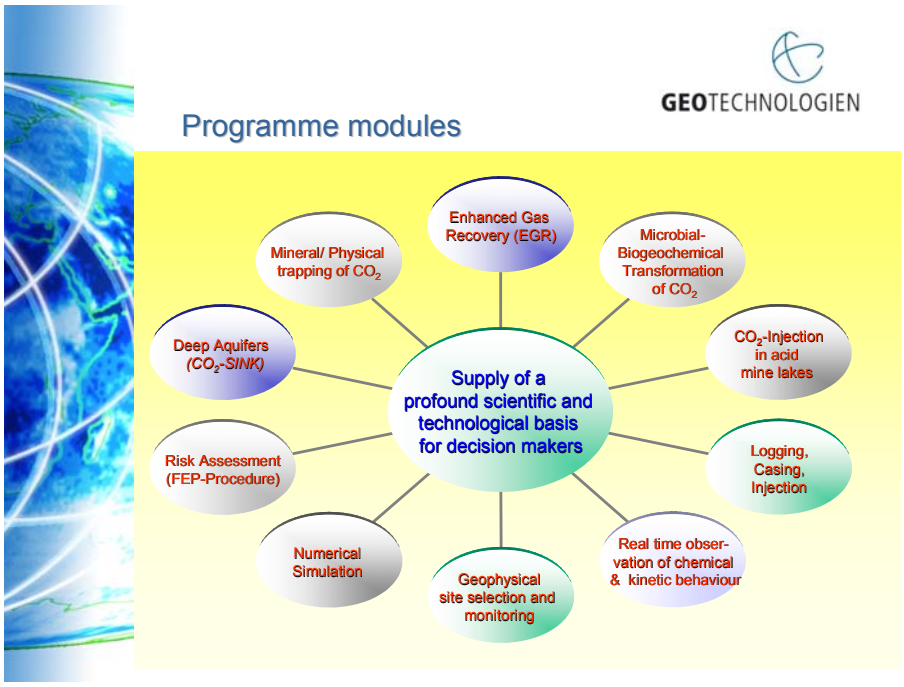

Fig. 4: Research activities in the R&D-Programme "Geological Storage of CO_2 in Germany"

Technologies for a safe and permanent storage of CO_2

Beside the further development and testing of more established technologies several of the funded projects focus on new approaches which received only little attention up to now. First objective of the project *CO_2-TRAP* e.g. is the conversion of dissolved CO_2 into the geochemically stable form of calcite using cooled water from geothermal energy use. Prime goal of this project is to develop a scientifically and technically feasible new technology in which Carbon Capture & Storage (CCS) and the geothermal energy use are combined to achieve a safe and economically attractive long-term storage of CO_2 trapped in minerals. The second focus of the *CO_2Trap project* is the physical trapping of CO_2 by sorption on residual coal and dispersed organic matter in formation damage zones of abandoned coal mines, thus expanding the approach of the EU project RECOPOL. This sub-project also investigates the utilisation of waste coal dust as a sorbent for CO_2 in combination with its deposition in abandoned mine workings. (Lead Management: Technical University Aachen).

Another topic is the recycling of sequestered CO_2 by microbial and biochemical transformation in the deep subsurface and the autotrophic methane formation in a mid- to long term timescale. The overall objective of the joint research project *RECOBIO* is to study the impact of CO_2 on the microbial biocenosis of relevant deep geological formations. Main focus is on the autotrophic methane formation in a mid- to long term timescale. This process provides the possibility of CO_2 recycling to CH_4 as a "fossil" energy resource. (Lead Management: Technical University Freiberg).

More than 50% of the German gas reservoirs are already in the mature state. Mature gas fields, however, offer the opportunity to enhance residual gas production through CO_2 injection, to extend the production lifetime and to increase their ultimate gas recovery. However, CO_2-EGR is still mainly a theoretical concept, that has been so far tested only in a very limited number of fields worldwide. In the project *CO_2EGR - Feasibility Study on the Potential of CO_2 Storage for Enhanced Gas Recovery in Mature German Gas Reservoirs* - two different geological settings of German gas reservoirs will be studied: (i) heterogeneous, fine-scale structured reservoirs in fractured low permeable Rotliegend Sandstones and (ii) rather homogeneous, large-scale-structured, Bunter sandstone reservoirs. (Lead Management: Technical University Clausthal-Zellerfeld and BGR Hannover).

The concept of the *CDEAL* project is to combine CO_2 mineral trapping and treatment of acidic mine waters. In the Lausitz (Lusatia) mining district intensive mining during the last century has produced huge deposits of fly ash, carbon slurry and iron sludge in the abandoned and flooded mine pits. A treatment of these sediments and water with CO_2 appears thermodynamically feasible using carbonation. Kinetic aspects and technical aspects of the dosage, mixing, precipitation, and settling of the carbonate solid will be investigated under this project. *CDEAL* will perform laboratory experiments in the first stage followed by a feasibility study at an open pit lake. (Lead Management: Technical University Freiberg).

Methods and technologies for a permanent monitoring

For underground storage of CO_2, it is essential to identify appropriate storage formations in the subsurface and to thoroughly evaluate their long-term safety. For this reason the programme will provide and implement a portfolio of cost-effective techniques for underground investigation and monitoring. In the context of hydrocarbon exploration, reflection seismic surveys have proven to be an appropriate tool for obtaining a structural image of the subsurface and to investigate its properties as storage formations. To improve the quality of 3D seismic data the *CO_2CRS project* seeks to apply specific data processing methods. One such model-independent stacking method is the so-called Common-Reflection-Surface (CRS) stack method. In contrast to conventional stacking methods, the CRS stack uses all information contained in the data. It thus yields seismic images of significantly improved quality, that resolve the subsurface as a function of reflection time, to generate a high-resolution structural depth image of the subsurface. (Lead Management: TEEC Isernhagen).

Another effective tool will be the geochemical real time observation of the migration of CO_2 within the reservoir and the rate at which CO_2 dissolves in saline aquifers. Therefore, the main objective of the *CHEMKIN* project is the development of new sensor concepts and down hole measuring methods and the practical demonstration of the various benefits of a permanent geochemical monitoring system. In addition to geophysical measurements, the geochemical real time observation at depth represents the sole method for gaining direct and continuous information. (Lead Management: GeoForschungsZentrum Potsdam).

The COSMOS joint project aims at developing and adapting scientific and technical methods for maximizing safe geological storage of carbon dioxide (CO_2) in saline aquifers and for verifying injection and migration processes. A major topic is the selection of injection well components with consideration of the specific properties of CO_2 and CO_2-bearing fluids. The emphasis is on the long-term stability of borehole cement and well equipment under the specific conditions of CO_2 storage in saline aquifers. All field measurements carried out at the test-site of the EU Project CO_2SINK are accompanied by small-scale laboratory experiments under simulated in-situ pressure and temperature conditions. (Lead Management: GeoForschungsZentrum Potsdam).

Fig. 5: The R&D-Programme in the "Greenhouse Issues" No. 81; March 2006

The recently started projects represent a key element in the organization of German research in the field of CO_2 storage and are a central component of the national network that is active in both European and international projects. All who are interested in the upcoming activities of the projects - from Germany, Europe or overseas - are welcome to share their ideas and results. Additional information on all joint projects and on details for contacting the coordinator can be found on the web-page of the R&D-Programme GEOTECHNOLOGIEN: www.geotechnologien.de or stroink@gfz-potsdam.de.

Public communication and outreach

A considerable effort in favour of public awareness and dialogue must accompany all activities concerning Carbon Capture and Storage. They guarantee transparency and independent oversight of this new technology. For this reason the coordination office for the R&D-Programm GEOTECHOLOGIEN initiated some special activities to bring the topic to a broader public.

The travelling exhibition "*Going underground - The world beneath our feet"* dealt with the various opportunities for a sustainable use of the underground. One part of the exhibition was dedicated to the save CO_2-storage in Germany. Between March 2004 and October 2005 the exhibition travelled throughout six German cities (Stuttgart, Leipzig, Dortmund, Berlin, München, Bremerhaven) with stops in the world famous technical museums of Munich and Berlin. More than 120.000 visitors enjoyed the journey to the underground and the national media reported regularly on it.

Another successful public event was a meeting of representatives from academia and industry with Members of the German Parliament and other decision makers. The meeting took place in the House of the German Press (Haus der Bundespressekonferenz) in Berlin. More than 160 guests followed the panel discussion with

State Secretary Kasparick from the Federal Ministry of Education and Research, scientists, and representatives from industry. Members of the German Parliament adopted the CCS topic and discussed the ecologic and economic opportunities of this technology with the audience. A small science fair presented the new developments in this field.

Fig. 6: "Going underground" – a travelling exhibition throughout Germany

Fig. 7: Regular meetings with politicians and other decision makers

Moreover a strong and very effective cooperation with representatives from the media has been established during the last years. As a result the main national newspapers, public magazines and numerous radio and V stations have been reported on the different activities concerning CCS in Germany.