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CO_2-Speicherung oder Geothermie ?

Michael Kühn und Ernst Huenges über gemeinsame und konkurrierende Nutzungsinteressen im Untergrund

Der bisherige Entwurf des CCS-Gesetzes löste eine intensive politische Diskussion über die Nutzung des Untergrundes für CO2-Speicherung und Geothermie aus. Das GFZ betreibt als weltweit einzige Forschungseinrichtung zwei entsprechende Pilotstandorte. Die GeoForschungsZeitung befragte die Projektleiter zu diesem Thema.

Bestehen konkurrierende Nutzungsinteressen zwischen Geothermie und CO2-Speicherung?

Kühn: Tatsache ist, dass sich Geothermie an den gleichen Orten nutzen lässt, an denen auch CO2 gespeichert werden kann und umgekehrt. Was an den jeweiligen Standorten gemacht wird oder ob der Untergrund sogar für beides genutzt werden kann, muss jeweils individuell anhand der Rahmenbedingung entschieden werden.

An welchen Standorten könnte es Interessenskonflikte geben?

Huenges: In Deutschland gibt es drei Regionen, in denen die tiefe Geothermie bevorzugt genutzt werden könnte: Das süddeutsche Molassebecken, der Oberrheingraben und das Norddeutsche Becken. Genau diese Regionen hat die Bundesanstalt für Geowissenschaften und Rohstoffe auch für eine mögliche CO2-Speicherung ausgewiesen. Die größten CO2-Quellen sind die Kohlekraftwerke in NRW und in Brandenburg. Aufgrund des aufwendigen Transports für das CO2 besteht deshalb vor allem im Norddeutschen Becken, in dem die größten geothermischen Ressourcen liegen, ein Bedarf zur CO2-Speicherung. Leider ist die Geothermie noch nicht so weit entwickelt, dass planbar gewinnbringend investiert werden könnte. Aus industrieller Sicht ist es daher verständlich, dass große Energieversorger mit ihrer Finanzkraft ihrem aktuellen Problem der CO2-Entsorgung den Vorrang geben, gegenüber einer langfristigen Investition in die Geothermie.

Kühn: Wenn man langfristig plant, dann darf man die Entscheidung nicht allein am Geld festmachen, denn die einzelnen Standorte sind unterschiedlich gewichtet. Während geothermische Strom- und Wärmeerzeugung in Stadtrandlage von Interesse ist, wird die Speicherung von CO2 eher in ländlichen Regionen stattfinden. Wir sind noch am Anfang mit der Beantwortung der Fragen: Wo sollte man welche Technologie einsetzen? Wo sind beide einsetzbar? Wo keine von beiden?

Gibt es die Möglichkeit paralleler Nutzung beispielsweise in unterschiedlichen Stockwerken?

Kühn: Für die CO2-Speicherung im industriellen Maßstab kommen alle Grundwasserspeicher ab einer Tiefe von 1 000 Metern in Frage. Für die Geothermie heißt es: Je tiefer desto wärmer und damit besser. Es stellt sich hier die Frage, ob es möglich sein wird, oberhalb von einem geothermischen Reservoir auch CO2 zu speichern. Aus bergrechtlicher Sicht ergibt sich in diesem Fall das juristische Problem, dass die Verantwortlichkeit nicht eindeutig abgegrenzt werden kann. Außerdem muss gewährleistet sein, dass die Bohrung durch einen CO2-Speicher hindurch sehr langfristig dicht sein muss.

Huenges: Technisch ist es jedenfalls möglich die unterschiedlichen Stockwerke zu nutzen. Ein wichtiges Stichwort ist hier die Sicherheit des Bohrlochausbaus, das heißt wir müssen die durchbohrten Horizonte zuverlässig versiegeln können.

Kühn: Hier besteht ein großer Forschungsbedarf. Wir müssen herausfinden, wie sich die Materialien (Zement und Stahl) im Kontakt mit den im Untergrund vorhandenen Salzwässern in Verbindung mit der Kohlensäure (CO2) verhalten. Es bietet sich auch die Möglichkeit, neben der CO2-Injektion aus einem Speicher gleichzeitig Wasser über Entlastungsbohrungen zu entnehmen. Dieses Wasser könnte geothermisch genutzt werden. All diesen Fragen stellen wir uns, um herausfinden, ob beide Technologien an einem Standort eingesetzt werden können.

Welche Synergien und Risiken ergeben sich durch die Erforschung beider Themen am GFZ?

Huenges: Es gibt kein Risiko durch die Erforschung. Vielmehr können wir in der Technologie-Entwicklung Synergien nutzen: in der bohrtechnologischen Erschließung, im Reservoir-Engineering und im Monitoring. Wir versuchen in beiden Forschungsgebieten den Problemen mit unverzichtbaren Pilotanlagen auf den Grund zu gehen.

Kühn: Ich sehe ebenfalls kein Risiko, sondern ganz im Gegenteil die einzigartige Chance, dass wir weltweit DAS Institut für Geowissenschaften sind, welches in der Lage ist, hier eine Antwort zu finden. Wir haben hier die Chance, einen erheblichen Beitrag für die Gesellschaft zu diesem Thema zu leisten.

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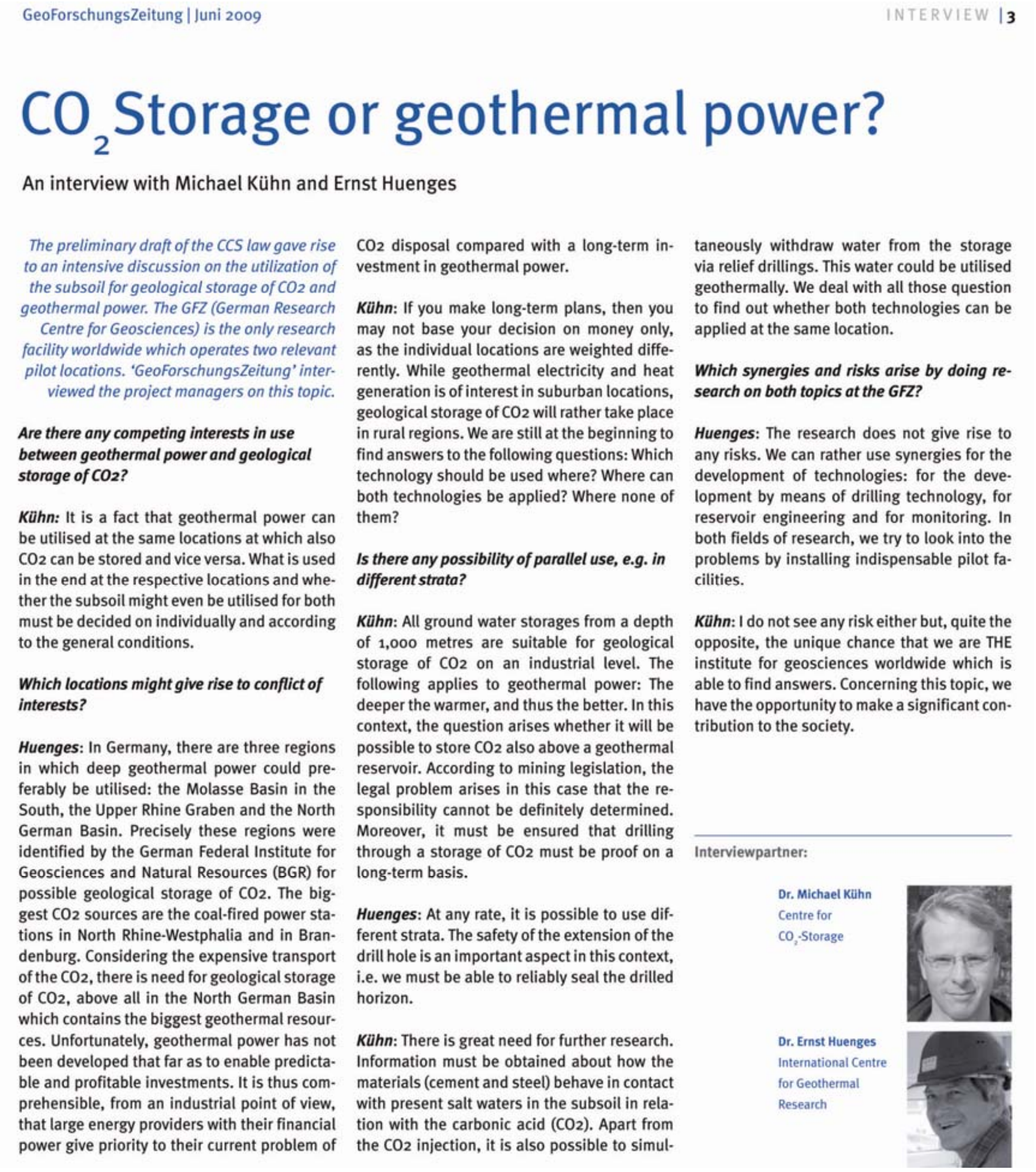

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CO_2 Storage or geothermal power?

An interview with Michael Kühn and Ernst Huenges

The preliminary draft of the CCS law gave rise to an intensive discussion on the utilization of the subsoil for geological storage of CO2 and geothermal power. The GFZ (German Research Centre for Geosciences) is the only research facility worldwide which operates two relevant pilot locations. 'GeoForschungsZeitung' interviewed the project managers on this topic.

Are there any competing interests in use between geothermal power and geological storage of CO2?

Kühn: It is a fact that geothermal power can be utilised at the same locations at which also CO2 can be stored and vice versa. What is used in the end at the respective locations and whether the subsoil might even be utilised for both must be decided on individually and according to the general conditions.

Which locations might give rise to conflict of interests?

Huenges: In Germany, there are three regions in which deep geothermal power could preferably be utilised: the Molasse Basin in the South, the Upper Rhine Graben and the North German Basin. Precisely these regions were identified by the German Federal Institute for Geosciences and Natural Resources (BGR) for possible geological storage of CO2. The biggest CO2 sources are the coal-fired power stations in North Rhine-Westphalia and in Brandenburg. Considering the expensive transport of the CO2, there is need for geological storage of CO2, above all in the North German Basin which contains the biggest geothermal resources. Unfortunately, geothermal power has not been developed that far as to enable predictable and profitable investments. It is thus comprehensible, from an industrial point of view, that large energy providers with their financial power give priority to their current problem of CO2 disposal compared with a long-term investment in geothermal power.

Kühn: If you make long-term plans, then you may not base your decision on money only, as the individual locations are weighted differently. While geothermal electricity and heat generation is of interest in suburban locations, geological storage of CO2 will rather take place in rural regions. We are still at the beginning to find answers to the following questions: Which technology should be used where? Where can both technologies be applied? Where none of them?

Is there any possibility of parallel use, e.g. in different strata?

Kühn: All ground water storages from a depth of 1,000 metres are suitable for geological storage of CO2 on an industrial level. The following applies to geothermal power: The deeper the warmer, and thus the better. In this context, the question arises whether it will be possible to store CO2 also above a geothermal reservoir. According to mining legislation, the legal problem arises in this case that the responsibility cannot be definitely determined. Moreover, it must be ensured that drilling through a storage of CO2 must be proof on a long-term basis.

Huenges: At any rate, it is possible to use different strata. The safety of the extension of the drill hole is an important aspect in this context, i.e. we must be able to reliably seal the drilled horizon.

Kühn: There is great need for further research. Information must be obtained about how the materials (cement and steel) behave in contact with present salt waters in the subsoil in relation with the carbonic acid (CO2). Apart from the CO2 injection, it is also possible to simultaneously withdraw water from the storage via relief drillings. This water could be utilised geothermally. We deal with all those question to find out whether both technologies can be applied at the same location.

Which synergies and risks arise by doing research on both topics at the GFZ?

Huenges: The research does not give rise to any risks. We can rather use synergies for the development of technologies: for the development by means of drilling technology, for reservoir engineering and for monitoring. In both fields of research, we try to look into the problems by installing indispensable pilot facilities.

Kühn: I do not see any risk either but, quite the opposite, the unique chance that we are THE institute for geosciences worldwide which is able to find answers. Concerning this topic, we have the opportunity to make a significant contribution to the society.

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Translation of an interview originally given in German

Geothermal energy provision and/or CO_2 storage using deep saline aquifers – lessons learnt from operational in situ laboratories

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Within the future mix of renewable energies, geothermal has the potential to provide huge amounts of sustainable, CO_2-effective, commercial base load power. International activities in geothermal research and development are increasing, particular in the USA, Australia, and Europe through coordinated programmes. In Germany, investments in geothermal research already triggers a growing interest in industry, which is based on increasing added value potential by generating energy and by exporting reliable geothermal plant systems components.

The subsurface geothermal research activities are strongly cross-linked with CO_2 storage in appropriate geological formations and to geoscientific competence fields in geochemistry, geophysics, and geology. In all these endeavors public awareness and outreach are becoming increasingly important. For example, in the field of geothermal energy provision or CO_2 storage, both economic sustainability and public acceptance are important prerequisites for the application of relevant research results.

Substantial research and technology developments are done to lead both technologies, geothermal provision of electricity and CO_2 storage, to public acceptance and economic viability. Although the use of geothermal heat is already a growing technology which will experience a considerably increasing market penetration in the near future, further research efforts are needed to make this technology reliable and cost efficient. Holistic research approaches bringing together the subsurface and surface technology expertise is the main approach of the GFZ in order to strengthen commercial utilization of the required techniques. Two huge in situ laboratories are installed under the leadership of GFZ (1) in the two more than 4 km deep geothermal research wells of Groß Schönebeck installed to develop strategies of enhanced geothermal systems and (2) in the three about 800 m deep research boreholes in Ketzin drilled to inject several ten thousand tonnes CO_2 and to monitor though induced processes. State of the art research approaches with special respect to these research activities using large scale operating systems will be reported.

Future research demand is required to address a number of open questions which exist in the field of common utilization of deep aquifers. This challenge has to be solved in order to fulfill demands on sustainable geothermal fluid flow and longtime integrity of CO_2 storage. Modelling approaches has to be verified by large scale experiments doing both recovering geothermal energy and store CO_2. Measures and monitoring systems similar to them developed for the Groß Schönebeck and Ketzin projects are required to control these operations. Future regulations to solve competitively the interest of common target areas have to be developed based on the impact of the application of the technology on mitigation of climatic change and on the reliability of future energy provision.

Shaping the energy future – new technologies in the context of climate change

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The great task of the 21st century is to limit global climate change. To avoid major catastrophic events, greenhouse gas emissions have to be reduced throughout all areas in a significant manner. This is especially challenging within the energy sector as huge amounts of CO_2 are emitted into the atmosphere by converting fossil fuels to energy. In the current discussion, there are several approaches to change the energy framework and to shape a new energy system. In the presentation, besides the description of the overall challenge and the general possibilities to limit climate change, with Carbon Capture and Storage (CCS) and geothermal energy two promising technologies are discussed.

CCS that means that CO_2 emissions from fossil-fuelled power plants, industrial sources or biomass production will be captured, transported and stored in the geological underground is technically available but still at very high costs and so far only in smaller scale than necessary for the application in huge power plants. Various rather smaller demonstration plants are working throughout the world and the upgrade to bigger facilities is under way and among others supported by the European Union. In the EU six power plant projects have been selected in 2009 to receive a substantial EU-funding as a major step for further development and the future market introduction of CCS. From today’s perspective, it is supposed that the technology will be commercially available between 2025 and 2030. The capture process is applicable (though with high efficiency losses) and the transport of CO_2 through pipelines has been shown in the US in particular for enhanced oil recovery projects. Most important and insecure in the CCS chain is the deposition of CO_2 and the available underground reservoir space which guarantees a safe and long-term stable storage.

The market introduction of CCS will depend on several aspects. Besides the demand for suitable storage capacities there are many more factors like ecological and economic impacts, the question of system compatibility and last but not least the public perception of CCS determining if and to what extent CCS will be part of the energy system of the future. Furthermore, recent studies show that the storage space for CO_2 is not only limited from a geological point of view, but it has to be divided between or shared by different forms of usage.

CCS can be used for power-plant emissions as well as combined with CO_2 from industrial point sources or biomass production. As industrial process emissions are less easy to substitute by renewable energies than fossil energy production, these emissions should be primarily sequestered. Another advantage is that many industrial applications provide a more concentrated stream of CO_2 after the capture process, so that the following steps can be achieved more efficiently. The other prospective form of CCS with biomass could lead to net-negative emissions which could be needed from 2070 onwards following recently published mitigation scenarios.

It is widely understood that the energy world of the longer term future have to be completely supplied by renewable energies. Wind is supposed to have the highest share (in particular in Europe) but geothermal energy can be also contribute substantially. Today, the energy system is static and provide huge full load from big plants. The shift towards a system with high penetration of renewable energies will decrease the demand for base load power plants. It will lead to significantly less full load hours for the conventional power plans than today making the life especially for fix cost intensive power plants much more difficult. However, the fluctuating energy provision has to be supplemented with efficient plants, providing high power dynamics. This shift in energy supply should be accompanied by a change on the demand side with smart energy solutions and more flexible consumers. The changing deliverable energy for households should be used most efficiently, e.g. by driving energy-intensive actions when energy supply peaks supported by variable prices. The most promising approach would be an intelligent energy supply system accompanied by a smart-grid where many different renewable energy sources are combined in one system, levelling out some of the fluctuations in the grid and combined with smart energy usage. Nevertheless integrating renewable energies with base load characteristic as geothermal energy would be more than helpful to cover all future challenges and to support the stability of the resulting system.

Both CCS and petrothermal projects, which are the most potential form of geothermal energy production, are dependent of available geological formations. There could be a potential conflict of usage although the needed depth is supposed to be slightly deeper (3,000 to 6,000 m) than for CO_2 injections (1,000 to 2,500 m). The underground space may also be used by natural gas storage to control demand peaks in winter time. Further underground applications are compressed-air- or hydrogen-storage which might be used in the future to compensate fluctuation due to the increasing share of renewable energies.

It is a question of strategic planning, which form of usage is regarded as most effective and to what time. So the regulation has to consider the various forms of competition. Several systematic problems are still unsolved and should be taken into account by regulators. The shift in the energy system has still to come and CCS as well as geothermal energy may contribute to the necessarily needed decarbonised new energy framework. All techniques should be demonstrated and researched so that the most effective path can be selected and action be taken. It has to be ensured that the distribution of underground space considers future technology developments and does not favour one option. An early and unconditional commitment towards CCS should be avoided in order to prevent limitation of alternative underground use as geothermal energy projects for instance.

High resolution aquifer characterization and 3D subsurface information systems: a way forward to assess competing and complementary potential for geothermal energy production and CO_2 storage

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Deep sedimentary aquifer systems (> 1000 m) can be an important geothermal energy source, and can serve as storage sites for CO_2. Key to assess the potential for geothermal production and/or CO_2 storage is a quantitative characterization of aquifer properties, including underlying uncertainties, and using performance models, based on distinct criteria, to outline competing and complementary potential. The Netherlands stand out in its free access to subsurface data, which has been collected over the past 30 years by the oil and gas industry. This paper describes the development of a dedicated geothermal information system based system on this information and its implications for both geothermal energy as well as CO_2 storage.

In the recent years the uptake of geothermal energy through implementation of low enthalpy geothermal production systems for both electricity and heating have been growing rapidly in north-western Europe. Geothermal exploration and production takes largely place in sedimentary basins at depths from 2 to 5 km. Geothermal activities can take considerable advantage from a wealth of existing oil and gas data.

To governmental bodies, such as geological surveys, it is a major challenge to put relevant oil and gas data and derived subsurface structural, temperature, and flow property models available to the geothermal community and to facilitate in quantitative assessment of geothermal potential of targeted areas, for both heat and electricity production (EGS). In order to face this challenge and responding to a geothermal boom as reflected by over 50 exploration license requests, TNO has developed a public web-based 3D information system, called thermoGIS.

ThermoGIS integrates a wealth of information of the subsurface worth over 50 billion Euros, which has been collected over the past 30 years by the oil and gas industry. Only recently it has been recognized that the datasets serve as excellent starting point for geothermal exploration, for known reservoirs at depth levels of 1500-3500 m for heat. However, up till now public mapping campaigns did not focus on geothermal reservoir and properties therein. In response to these needs, TNO has generated a detailed geothermal characterization, including mapping of over 8 aquifer levels, their flow properties and temperatures at a resolution of 250 m. State-of-the-art 3D modeling techniques have been used and developed to obtain the reservoir structures, flow properties and temperatures, using constraints from deep wells, and detailed subsurface mapping from 3D and 2D seismic.

ThermoGIS allows to asses quickly key parameters such as depth, thickness, temperature and flow properties, which can be used equally well for geothermal production as well as CO_2 storage performance. Tools allow to draw sections highlighting particular reservoirs and navigate simultaneously in geographic contexts tailored to societal needs, and allows to perform a performance assessment at arbitrary location to screen suitability for geothermal heat production. In future this will be extended to assess CO_2 storage performance.

Key criteria for geothermal energy production and CO_2 storage are in part similar and in part considerably different. Both require sufficiently high transmissivity in order to sustain sufficiently high flow rates, however in CO_2 storage the (pressure-connected) aquifer extent should be large whereas for geothermal this is much less important. Both require a sufficiently high depth value: for geothermal the minimum depth is dependent on the required production temperature, whereas for CO_2 storage supercritical pressure conditions are important. Further stored CO_2 is preferentially confined to a trap structure, and requires a seal overlying the aquifer. Geothermal production is well received in densely populated areas, whereas CO_2 storage may not. Economically, geothermal heat production is generally tightly constrained by subsurface economics and local demand, whereas for CO_2 storage, surface capture and transport costs dominate.

Based on thermoGIS we show the effect of the different criteria and demonstrate the added value of a public information-system such as thermoGIS to jointly predict the potential of geothermal energy and CO_2 storage and to improve policy decisions.

Geology of carbon dioxide storage compared to enhanced geothermal systems

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The growth of industrial economies, and the emergence of newly industrializing economies produces an increasing demand for energy. This demand is met mostly by combustion of fossil fuel for electricity, transport, and heat production. The consequent emissions of fossil derived CO_2 are implicated to cause lower atmosphere warming, climate change, and acidification of near-surface ocean water. This situation can be ameliorated by : carbon capture and geological storage (CCS) of the CO_2 injected deep below ground; production of heat and power by non-fossil energy sources, such as nuclear fission of uranium, solar, wind, wave or heat mining (EGS); or by capture of CO_2 from air, or storage of CO_2 derived from biomass – resulting in negative emissions.

Of these, CCS is currently receiving unprecedented attention from established power generators, and support from EU and Member State governments. Six projects have received funding from the EERP, and at least an additional six are projected. CCS has advantages in that I permits continued use of an centralized system for electricity production and distribution similar to the past 50 years, enabling direct and large reductions of emissions in a short timescale (from 2020). The tonnages of CO_2 required to be captures from power plant and injected are truly immense 200 Mtonnes/yr for UK power plants, or about 700 Mtonnes/yr CO_2 from power plants in NW Europe. Storage of this CO_2 in the subsurface requires: a thick layer (tens of meters) of porous reservoir rock, overlain by an impermeable seal rock, deeper than 800m below ground level. Such combinations are abundant in sedimentary basins, and are proven to retain buoyant fluids (such as oil, methane or CO_2) in hydrocarbon provinces.

Targets for CO_2 injection are three-fold. 1) Oilfields where injection of CO_2 can be used to increase production volumes (resulting in approximately equal storage of waste carbon, compared to extra carbon produced). 2) Depleted gasfields, where CO_2 can re-pressurise the porespace fluids up close to original discovery values. This can store net carbon, in structures proven to retain methane for tens of millions of years. 3) Sal-water filled formations “aquifers” where CO_2 must displace ambient pore fluid and may pressurise the system above its natural equilibrium.

Of these, oil and gas fields are locally well-defined structures, usually with intense acquired and analysed data from hydrocarbon production. The physical migration of CO_2 laterally outwith the structure is not expected and so these are potentially available to monitor CO_2 behaviour intensively during and after injection. However these storage volumes available are sufficient for initial CCS projects, but cannot accommodate full-scale and long-term (50-100 yr) rollout of CCS as a continental scale European storage option. There may be conflicts of use with similar sites required for annual storage of methane gas, and public objection to CO_2 storage has become vocal in Denmark Netherlands and Germany. However commercially useful methane stores have characteristics enabling rapid injection and rapid recovery of gas with minimum or no hydrocarbon production, and so favour small sites close to gas network pipelines. Many gas stores already exist, so that the addition of very large additional capacity is not critical.

Saline formations are by far the largest opportunities for CO_2 storage, with about 10 times the capacity of hydrocarbon fields. However the injected CO_2 may migrate long distances (tens km) laterally and be more difficult to monitor. The additional fluid volumes may also increase reservoir pressures to the point of fracture, with such pressure effects extending tens of km laterally from an injector borehole. Ideal sites are cool (keeping CO_2 fluid), laterally extensive, sealed to vertical fluid motion, deeper than 800m (to keep CO_2 fluid) but shallower than 4km (to exploit uncompartmentalised reservoirs with adequate porosity and permeability). Rival uses are hydrocarbon production from accumulations in the same formation or, potentially, the large-scale circulation of saline porewaters to mine heat.

Of the rival options (above) to supply renewable energy, the use of heat mining in Enhanced Geothermal Systems (EGS) is sometimes discussed. At present this technology option only exists commercially at a few sites in EU and worldwide. Premier targets have been locations where enhanced temperature gradients already exist (to access warm fluids without drilling too deep). Ideal temperatures are conventionally considered to be 150 °C, so that in regions of normal temperature gradient, this resource lies deeper than 4km and so does not conflict directly with CCS assets. Trial projects (notably at Soultz and Berne) have induced unpredictable shallow earthquakes M 2.5-3.5, which has contributed to negative public perception and closure of the projects. Novel play types are under investigation, for example in granites beneath sedimentary cover, but have so far no been commercialized. The intake areas of water circulation for EGS projects are restricted to several km around the surface power plant site, so are local relative to the regional many tens km required by CO_2 injection. If CO_2 were injected into those fluids, then additional more expensive corrosion-resistant borehole equipment may be needed. This already exists in wet natural hydrothermal exploitation. EGS does not directly reduce CO_2 (although a static volume of CO_2 can be used as a heat carrier fluid), but could be argued to displace coal combustion emissions to produce heat and electricity.

The European scale maps of potential CCS stores in aquifers and hydrocarbon fields are compared to the maps for potential EGS sites. There is little overlap, and such conflicts seem capable of resolution by national planning considering not only the areal footprint but also the vertical 3D licensing impacts and safeguards. In the medium term it is possible that conflicts with EGS may be eliminated if large scale CO_2 storage is developed offshore. Given that the number of CCS sites in prospect is at present only 12 within the EU, and that several of these will initially be injecting offshore or into defined subsurface structures, the scope for large scale pollution of the EGS resource appears speculative rather than real. The need to progress rapidly towards proving CCS for rapid reduction of CO_2 emissions from established and highly probable future fossil fuel burning is very much greater benefit than the CO_2 savings from EGS, or the benefit gained by delaying CCS for 5 or 10 years whilst EGS is investigated and proven. The two technologies can proceed in parallel, with minimal overlap of preferred 3D locations.

Modeling CO_2 geological storage

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The geological storage of CO_2 usually considers four stages such as exploration, operation, closure and post closure. Modeling tools are required in order to anticipate future storage behavior. As in the oil and gas industry, uncertainty about the storage behavior will decrease with time. Therefore, the modeling tools need to be updated throughout storage life time. In particular, the fate of CO_2 will be controlled by local storage condition (pressure and heterogeneities) and regional hydrodynamics. The main migration mechanisms such as buoyancy, dissolution, capillary and mineral trapping will be balanced depending on the conditions in the storage reservoir and its geosphere. This paper reviews the modeling issues during the different stage of the storage life time. Different tools may be applied given the different spatial scale of interest, i.e. near-wellbore, hydraulic unit, storage complex, and given the different time scale of interest, i.e. operation, long-term. To enable industrial scale storage (several million tons of CO_2 per year), Deep Saline Formations seem to offer the best potential. Besides the characterization challenges, possible interactions with other underground activities such as Underground Gas Storage, Oil & Gas Exploration and Production, or Enhanced Geothermal Systems, need to be carefully assessed. At early stage, analytical models enable estimate of the storage capacity and well potentially affected by the planned storage. Later on, during the exploration stage, more knowledge and data need to be incorporated and uncertainty assessed at the reservoir and storage complex scale. Numerical tools enable valuable integration and scenario assessment for both short and long term. However, these tools need to be back by appropriate site-specific data acquisition during characterization. In addition, regional hydrodynamics need to be integrated to enable assessment of interference with other underground activities. The modeling tools are the corner stone of storage application and should therefore support the storage industrial development and anticipate the appropriate monitoring and potential remediation programs. During the storage operation stage, the modeling tools are regularly confronted to the field data and updated as soon as deviations are observed. The modeling tools are then used in a predictive mode to assess potential storage evolution. Finally during the closure stage and beyond, the modeling tools will support the expected storage behavior.

Well integrity research for geological storage of CO_2 and its relationship to EGS well technology

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The potential for CO_2 leakage from wells is one of the key risks identified in the geological storage of CO_2. The long-term integrity of wellbore systems is of particular concern because of the potential for CO_2 to react with and degrade wellbore materials, principally Portland cement and carbon steel casing[1]. Some of the key questions include:

- What are the possible migration pathways for CO_2 along well systems?
- What components in the well system are most susceptible to degradation and lead to enhancement of leakage potential?
- What are the major degradation mechanisms that occur over the long term, which for geological storage can be defined as hundreds of years?; and
- How can permanence of storage with respect to well systems be monitored and verified?

The presentation will discuss a methodology to assess the transport properties of wells used in the geological storage of CO_2. The methodology provides a framework that systematically identifies and estimates the effect of each of the physical and chemical processes responsible for the response of active and abandoned wells, on their transport properties. Based on the physics involved in these permeability alteration mechanisms, a four-group classification is proposed: geomechanical damage, hydro-chemical damage, mud removal and deterioration damage (cement and casing). These mechanisms can occur during the various phases of a well life, namely, drilling, completion, production, and abandonment. Challenges associated with integrating real operational data into the performance assessment are discussed within the context of a performance assessment methodology.

For the full life cycle of geothermal energy developments, however, their overall environmental impacts are markedly lower than conventional fossil-fired and nuclear power plants because a geothermal energy source is contained underground, and the surface energy conversion equipment is relatively compact, making the overall footprint of the entire system small. Enhanced or engineered geothermal systems (EGS) power plants operating with closed-loop circulation also provide environmental benefits by having minimal greenhouse gas and other emissions. With geothermal

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[1] Crow et al., 2009. Wellbore integrity analysis of a natural CO_2 producer. Int. J. Greenhouse Gas Control, doi: 10.1016/j.ijggc.2009.10.010

energy, there is no need to physically mine materials from a subsurface resource, or to modify the earth's surface to a significant degree. However, there still are impacts that must be considered and managed if this energy resource is to be developed as part of a more environmentally sound, sustainable energy portfolio for the future. The major environmental issues for EGS are associated with ground-water use and contamination, with related concerns about induced seismicity or subsidence as a result of water injection and production. And with respect to well integrity and the geological storage of CO_2, it is within this realm of unintended subsurface movement of fluids along or within wellbores that is perhaps a common theme for both disciplines.

One of the biggest gaps in current EGS planning and understanding is well completion[2]. Current geothermal completions are generally openhole or at least present continuous communication throughout the production interval. This is in contrast to many oil and gas applications where complex completions are used in production intervals to more optimally engage the reservoir. The report suggests that the following issues should be investigated for EGS applications:

- Facilitation of selective stimulation along the production interval
- Controlling zonal injection to more effectively extract thermal resource from the formation
- Cost and functionally effective intervention to reduce injection loss
- Cost and functionally effective intervention to mitigate the effects of short circuiting
- Cost and functionally effective intervention to address production loss due to chemical or erosion effects

For the long term performance prediction of well systems in the geological storage of CO_2, many of the issues listed above are common elements for both technologies. The presentation will review current well integrity research in the area of CO_2 storage and identify common areas where synergistic research will provide value added knowledge for both engineered geothermal systems and CO_2 geological storage.

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[2] Yarom Polsky Y. et al, 2008. Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report. SAND2008-7866, 108 p.

Injection-induced seismicity

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Although cases of seismicity induced by human activities have been known and documented for decades, the seismic hazard associated with the exploitation of deep geothermal energy and possibly with future endeavours to store large amounts of CO_2 in the underground are often underestimated. Although there are several examples of successful geothermal and CO_2 storage operations that did not cause any felt earthquakes, recent cases of promising projects aimed at tapping geothermal energy at depths of several kilometres have raised serious public concern about the seismic risks associated with such projects. Among the reasons for underestimating the hazard of induced seismicity are fundamental misconceptions regarding the occurrence of natural seismicity and the processes which can trigger seismic events. Thus it is often thought that earthquakes occur only at greater depths (> 5 km) in the crystalline basement and that the shallower sedimentary rocks are not strong enough to store sufficient stress to produce significant earthquakes. Many examples documented in the seismological literature show that this is not true and that earthquakes with magnitudes of 5 and more can occur at depths of only a few km in the sedimentary cover. It is furthermore often believed that it requires massive perturbations of the state of stress to trigger earthquakes. This also is incorrect: increasing evidence suggests that large parts of the Earth's crust are quite near its point of failure (critically stressed) and that even small perturbations of the complex interaction between fluids and faults can decrease the resistance to failure sufficiently to trigger an earthquake. The injected fluids rarely exceed the level of the least compressive stress in the crust and it is not the amount or pressure of an injected fluid that supplies the energy to generate an earthquake. The fluids merely decrease the resistance to failure, and it is the ambient tectonic stress that drives the seismic activity. Among other aspects, this also means that the distinction between enhanced or engineered geothermal systems (EGS) on the one hand and hydrothermal systems on the other, although important, should not be overemphasized when it comes to assess the seismic hazard associated with such projects. Examples of natural seismicity at shallow depth such as the Magnitude 5 event of Annecy (France), the earthquake sequence of Fribourg (Switzerland) or rain-induced seismicity in Germany and Switzerland as well as seismicity induced by human activity (in particular the geothermal project of Basel) serve to illustrate these points.

The fundamental processes that lead to induced earthquakes are understood, however, we still are not able to quantify uniquely the relative importance of the different parameters (e.g. depth, ambient stress, rock friction, fluid pressures and volumes, etc.). Moreover, in individual cases we usually do not have sufficient information to assess the seismic hazard associated with a particular project before it is started. This poses significant problems for the project developers, the regulatory authorities and the public. New paradigms in the way deep geothermal projects and CO_2 storage facilities are regulated need to be established. The number of successful projects worldwide for the exploitation of deep geothermal energy and the storage of CO_2 is small, so that the empirical data base is limited and we are not able to say with confidence why some projects have caused felt earthquakes and others have not. Thus, if deep geothermal energy and the underground storage of CO_2 is to contribute significantly towards the mitigation of the global energy crisis and climate change, we need to openly exchange all the available information and engage in a constructive dialog among all stakeholders -- project developers, authorities, science and the public.

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Deichmann, N. & Giardini, D. 2009: Earthquakes induced by the stimulation of an enhanced geothermal system below Basel (Switzerland). Seismological Research Letters 80/5, 784–798, doi:10.1785/gssrl.80.5.784.

Giardini, D. 2009: Geothermal quake risks must be faced. Nature, 462, 848-849, (17. Dec. 2009).

Häring, M.O., Schanz, U., Ladner, F., Dyer, B.C. 2008: Characterization of the Basel 1 enhanced geothermal system. Geothermics 37, 469–495, doi:10.1016/j.geothermics.2008.06.002.

Kraft, T., Mai, P.M., Wiemer, S., Deichmann, N., Ripperger, J., Kästli, P., Bachmann, C., Fäh, D., Wössner, J., and Giardini, D. (2009): Mitigating Risk for Enhanced Geothermal Systems in Urban Areas. EOS Transactions American Geophysical Union, 90/32, 273–274.

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The complete Basel Risk Study and other reports can be downloaded from:
http://www.wsu.bs.ch/geothermie

Selected references regarding shallow and rain-induced seismicity:

Husen, S., Bachmann, C., Giardini, D. 2007: Locally triggered seismicity in the central Swiss Alps following the large rainfall event of August 2005. Geophys. J. Int. 171, 11261134 doi: 10.1111/j.1365-246X.2007.03561.x

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Thouvenot, F., Fréchet, J., Tapponier, P., Thomas, J.-Ch, Lebrun, B., Ménard, G., Lacassin, R., Jenatton, L., Grasso, J.-R., Coutant, O., Paul, A. & Hatzfeld, D. 1997: The Ml-5.3 Epagny (French Alps) earthquake of 15 July 1996: a long awaited event on the Vuache fault. Geophys. J. Int, 135, 876-892, 1998.

Thouvenot, F., Jenatton, L., Gratier, J.-P. 2009: 200-m-deep earthquake swarm in Tricastin (lower Rhône Valley, France) accounts for noisy seismicity over past centuries. Terra Nova, 21/3, 203-210, doi:10.1111/j.1365-3121.2009.00875.x

Insight into modern geothermal reservoir engineering and management practice

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Owing to the exhaustible nature of geothermal resources, sustainable heat mining is of utmost importance in designing and implementing relevant exploitation strategies aimed at reconciling users' demands with reservoir longevity concerns.

Sound and effective reservoir engineering allows developers to optimize energy extraction from a geothermal field and extend its commercial life.

The application of reservoir engineering begins during the exploration phase of the project with the analysis of the initial geophysical measurement data that indicate a promising geothermal system, and it continues throughout the operational life of the geothermal resource. It is the reservoir engineer's task to test wells, monitor their output, design new (make up, step out) wells, and predict the long-term performance of the reservoir and wells. This design and prediction is accomplished by studying field and operational measurement data and using computer models to project the field operation into the future in order to secure reservoir management. During operation of a geothermal field, the reservoir engineer will be able to compare the actual performance to the predicted performance. Whenever, the engineer can modify the exploitation strategy for the geothermal field to obtain more efficient operation.

Geothermal reservoir simulation is a technology that contributes to the important problem area of sustainable heat mining, and has become standard over the past decade. If sufficient information on the field is available then it is possible to construct numerical models of the reservoir and use these models to simulate field performance under a variety of conditions. Perhaps the most important and most challenging part of this process is the integration of information gathered by all the geo-scientific disciplines leading to the development of the conceptual model. The success of any reservoir modelling exercise is dependent upon the flow of high quality information from the basic data collection phase, through the conceptual modelling phase, to the simulation process. This flow of information must go both ways, as the modelling process is an interactive one, often requiring numerous reconstruction and reinterpretation.

Once a geothermal resource has been identified and the reservoir assessed leading to a conceptual model of the geothermal system, reservoir development and relevant management issues come into play.

In the broad sense, reservoir management is an extension of reservoir engineering. Whereas the latter addresses key issues such as heat in place, reservoir performance, well deliverabilities, heat recovery, water injection and reservoir life, reservoir management aims at optimised exploitation strategies in compliance with technical feasibility, economic viability and environmental safety requirements.

Nowadays reservoir engineers are required to construct a realistic conceptual model of the field including sub surface temperature and pressure distributions in both vertical and horizontal planes, the distribution of chemicals and gases, field boundaries, reservoir storage and transmissivity, and the flow of fluids both within the reservoir and across the boundaries. The sources of information from which the model is deduced address well test results and downhole measurements. The reliable interpretation of field measurements is therefore a major consideration for the reservoir engineer. The conceptual model of the field often provides sufficient understanding of the reservoir to enable informed and logical decisions on the field development and reservoir management issues.

My house has several levels – Co-habitation of CO_2 storage with Geothermal?

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In many areas around the globe exploration and exploitation of different natural resources is going on in parallel: mining, drinking water, geothermal, etc. In recent years the need for pore space storing CO_2 in the long term is adding another factor. In most countries the national authorities regulate and secure best use of all these natural resources.

Today we are exploring possible co-habitation or competition of two of the factors; geothermal energy and CO_2 storage.

CO_2 storage must – to utilise the available pore space to the maximum – be stored in dense phase above 80 bar pressure, i.e. deeper than 800-1000 m. The need to have a practical injectivity (porosity and permeability) limits the depth to 3000 – 4000 m. Need to have sufficient solid cap rock (overburden) makes deeper generally safer. The deeper the more costly it is to drill the necessary injection wells. Ideal depth is then around 1000 meter. At this level most areas of the world would produce formation water at 30 – 50 degrees Celsius; not much for geothermal?

CO_2 can be stored in salt water formations or (near) empty hydrocarbon fields. Studies clearly point at storage capacity in most areas of the world; not everywhere but not far away?

Injection of dense phase of CO_2 in the pore volume will displace formation water and inevitably – at least initially - increase the formation pressure and possibly ground surface uplift. Pressure increase and risk of breaking the cap rock often limits the storage capacity.

Underground flows of CO_2 and/or formation water can cause undesired migration into other formations, e.g. drinking water, in worst case leakages to the surface.

Drilling extra wells producing formation water can limit the pressure build-up and be used to steer the injected CO_2 plume, to avoid reaching leaky faults or old, not-so-safe wells. The production of formation water could be combined with geothermal energy production or vice-versa.

Examples:

Hellisheidi geothermal power plant on Iceland have now started to inject CO_2 coming from the geothermal water; a combined injection of some of the used produced water with CO_2 into a water stream 600 – 700 meter deep in the basalt layers.

A CO_2 storage project in Denmark is now evaluating delivering produced saline formation water into a new district heating system of a nearby village.

Conclusion:

The opportunities are many and in the end national authorities have to continue to balance all use of their resources, also geothermal energy and CO_2 storage.

GeoSynergy: Combining CO_2 storage and geothermal energy production – a case study

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Geological storage of CO_2 need not be in conflict with the use of the subsurface for the extraction of geothermal water even if it takes place in the same area. It does, however, require good forward planning to ensure that the two activities work in tandem rather than as obstacles to each other.

When exploring for geothermal opportunities the main objectives are temperature (depth) and a suitable porous reservoir with acceptable permeability/injectivity while no structural closure is required. Geological storage would be looking for the volume, containment and injectivity – features in may ways similar to those required for geothermal energy production but also most likely to be found within a large, deep structural closure such as a dome or anticline. While there are literally thousands of square kilometers of god quality Triassic and Jurassic reservoir sandstones within the North German and Danish-Norwegian Sedimentary Basins, the number of large structural closures suitable for CO2 storage is much more limited.

In Northern Denmark Vattenfall has since the beginning of 2008 worked on the development of a CCS demo project at Nordjyllandsværket, one of the world’s most efficient coal-fired power plants. Recently the status of the project has changed and the aim is now to develop this CCS project as one of the early commercial plants from 2020. Storage is intended to take place in a nearby structure discovered during oil exploration in the 1950’ies. A modern 2D seismic survey has been acquired and extensive numerical modeling of the structure indicates promising conditions.

At the same time as the CO_2 storage exploration is ongoing, initiatives are under ways to use the local geothermal heat resource. The target reservoir in both cases is a Triassic sandstone at about 2 kilometers depth. With the delay in the development of the CCS project, there is a likelihood that the need for geothermal water will occur some years before the CO_2 storage.

Using the data from the CCS project, the initial two geothermal wells can be properly placed and conventional production can be commenced which will also enable thorough hydraulic testing of the reservoir. After some years, one of the wells is converted for use as CO_2 injection point while a new well for disposal of cooled water is located outside the structural closure where it will have little or no impact on the storage pressure. In this manner the geothermal energy extraction provides storage space for the CO_2 which thus does not result in a pressure build-up zone surrounding the saturated volume.

A number of alternative solutions are discussed for disposal of cooled water and for reservoir management when filling the structural closure.

Forum - Discussions: Synergy or Competition?

Sustainable energy supply for Germany: CO_2 storage – help or hindrance?

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Electricity generation accounts for about 40% of total CO2 emissions in Germany. Therefore electricity supply must undergo a fundamental change if we want to achieve the long-term climate targets as part of sustainable development. Key elements of a changing strategy are reducing the demand for electricity through increase of efficiency and the continued expansion of renewable energies. In the long term, renewable energies must take on the bulk of electricity production. Potential for this exists in Germany and globally.

The key question is not about the capability of our present electricity system to integrate increasing amounts of renewable energy sources. It rather refers to the design of future systems that should be able to integrate renewable based electricity as effectively and cost-efficiently as possible.

This means major challenges for the overall system and new demands on conventional power plants: E.g. wind power with its feed-in fluctuations represents no baseload capacity itself and has a low capacity credit. However, it significantly reduces the residual base load, which has to be covered by conventional power plants. The expansion of renewable energy sources will, overall, distinctly reduce the future requirement for conventional base-load power plants.

Since alternating current cannot be stored directly on a large scale, fluctuations between production (feed-in) and consumption (load) must be compensated at all times. In order to integrate large amounts of renewable energies into our electricity supply, we need to exploit new technical possibilities. Renewable energies and also the demand side must be more heavily involved in balancing and the provision of balancing energy, for example in virtual power plants. Balancing on a large European scale also has considerable potential for offsetting fluctuations in the feed-in of electricity from renewable energy sources. In addition, a stock of highly flexible and low-emission fossil-fuel-fired power stations will be necessary - for a transitional period - to complement renewable energies.

The transition towards a sustainable energy system leads to several new tasks for underground use: Beyond mining as the predominant underground use of today there will be huge demand for energy related underground use e.g. geothermal energy, energy storage (gas, compressed air, hydrogen, heat or cooling energy) and possibly permanent storage of carbon dioxide from industry-related processes. In order to achieve optimum use of the underground it is therefore necessary to sort the tasks according to the natural potentials (supply side) and the long-term sustainability roadmap (demand side). A spatial underground planning should replace the first-come-first-serve principle of today's mining law and reserve exclusive areas for certain purposes. Nationwide underground mapping of the relevant geological properties is required as a basic planning tool. Further research is necessary to determine possibilities or impossibilities of overlapping use.

Legal framework of CCS: conflicting priorities of targeted rock formations

Legal framework of CCS: conflicting priorities of targeted rock formations

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- Richtlinie 2009/31/EG des Europäischen Parlaments und des Rates vom 23.04.2009 über die geologische Speicherung von Kohlendioxid und zur Änderung der Richtlinie 85/337/EWG des Rates sowie der Richtlinien 2000/60/EG, 2001/80/EG, 2004/35/EG, 2006/12/EG und 2008/1/EG des Europäischen Parlaments und des Rates sowie der Verordnung (EG) Nr. 1013/2006

  Art. 39 CCS-RL: Umsetzungsfrist 25.06.2011

- Aktueller Umsetzungsstand in Deutschland:
  Entwurf eines Artikelgesetzes zur Regelung von Abscheidung, Transport und dauerhafter Speicherung von Kohlendioxid, BR-Drs. 282/09 vom 03.04.2009

Abscheidung

Rechtsregime für die Abscheidungsanlagen: BImSchG
Zu diskutierende Fragen:
1) Hoheitliche Durchsetzbarkeit von CCS?
   § 5 Abs. 1 Satz 2 BImSchG i. V. m. §§ 5, 6 TEHG = lex specialis ggü. § 5 Abs. 1 Nr. 2 BImSchG (Vorsorge-Stand der Technik)
2) Vereinbarkeit mit dem Vorsorgeprinzip des § 5 Abs. 1 Nr. 2 BImSchG?
   Die CO_2-Abscheidung wird mit einer Zunahme der Emissionsfracht an SO_2, NO_X, Gesamtstaub führen.
3) Vereinbarkeit mit dem Energieeffizienzgebot des § 5 Abs. 1 Nr. 4 BImSchG?
   Wirkungsgradverluste von 10 % - 15 %
4) Änderung 13. BImSchV?
u. v. m.

Transport

Rechtsregime für das Pipelinenetz: Planfeststellungsverfahren als Trägerverfahren
Zu diskutierende Fragen:
1) Zuständigkeit hins. Linienführung/Planfeststellungsverfahren?
2) Verfahrensdauer?
   Regelungen zur Verfahrensbeschleunigung/zeitl. Vorverlagerung des Planfeststellungsverfahrens
3) Nutzung des Leitungsnetzes durch versch. Unternehmen:
   Zugangsrechte – Haftungsfragen im Falle von Leitungsschäden

4) Kostentragung für das Leitungsnetz
(Stichwort: windfall-profits)

u. v. m.

Speicherung

Rechtsregime speziell für die Speicherung von CO_2 aktuell: (-)
Bisherige Diskussion: KrW-/AbfG oder BBergG?
Zu diskutierende Fragen:

1) Verhältnis Untersuchungserlaubnis – Speichergenehmigung?
2) Konkurrierende Nutzungen/Genehmigungen?
Stichwort: Geothermie; bergrechtliche Erlaubnis zur Aufsuchung von Sole
3) Speichernutzung durch mehrere Unternehmen:
Haftung bei Einleitung von verunreinigtem CO_2 oder bei CO_2-Austritt?
4) Verhältnis CO_2-Speicher – Oberflächeneigentum
5) Schließung der Speicherstätte – Nachsorge und Nachhaftung

u. v. m.

Rechtliche Rahmenbedingungen der CO_2-Speicherung

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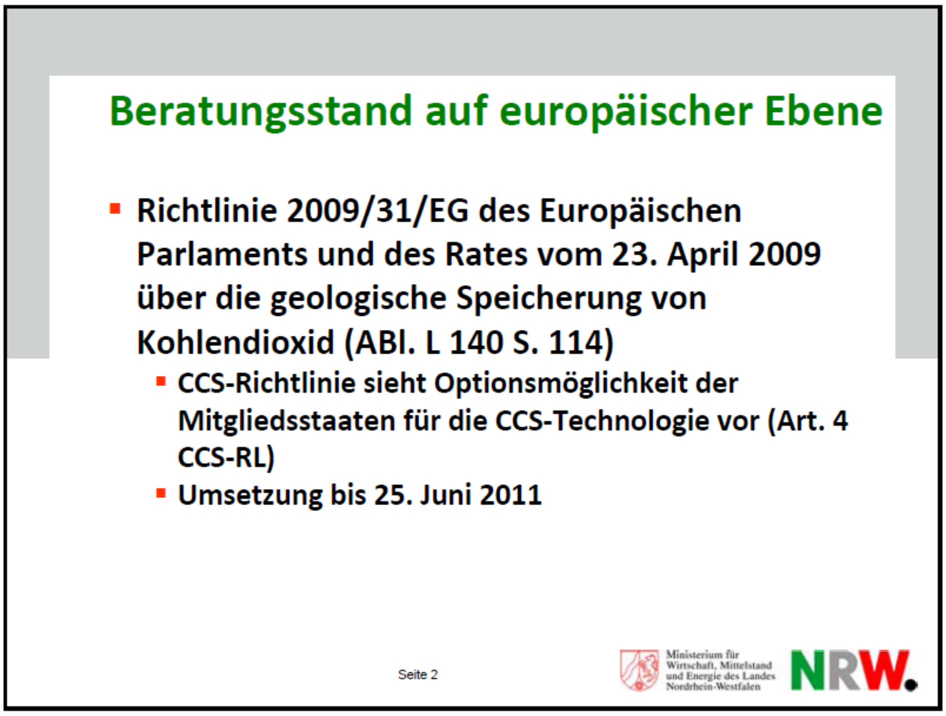
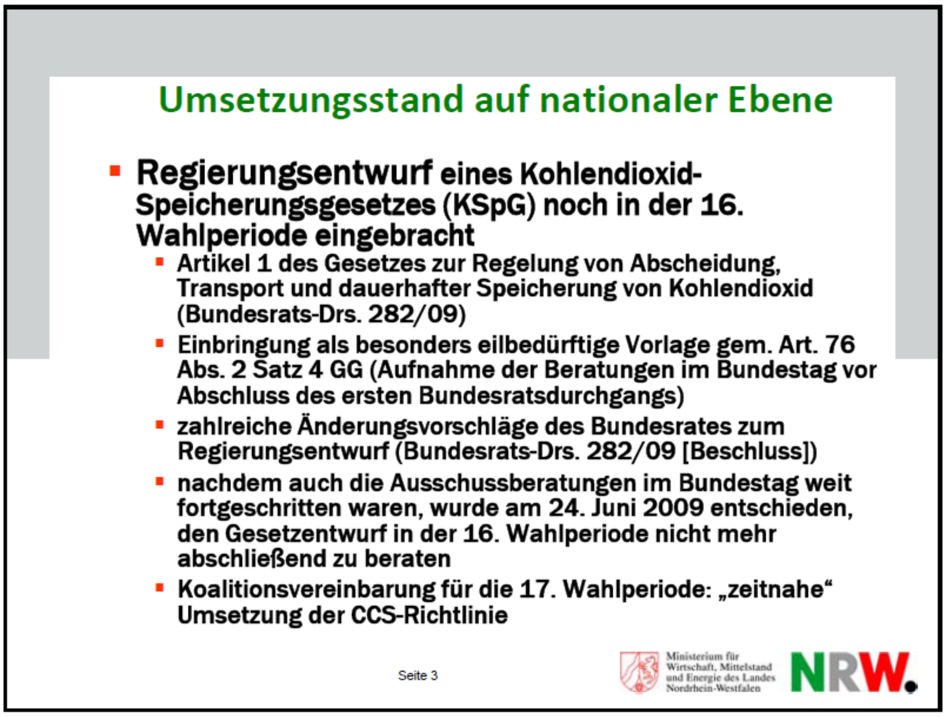


Beratungsstand auf europäischer Ebene

- Richtlinie 2009/31/EG des Europäischen Parlaments und des Rates vom 23. April 2009 über die geologische Speicherung von Kohlendioxid (ABl. L 140 S. 114)
  - CCS-Richtlinie sieht Optionsmöglichkeit der Mitgliedsstaaten für die CCS-Technologie vor (Art. 4 CCS-RL)
  - Umsetzung bis 25. Juni 2011

Seite 2



Umsetzungsstand auf nationaler Ebene

- Regierungsentwurf eines Kohlendioxid-Speicherungsgesetzes (KSpG) noch in der 16. Wahlperiode eingebracht
  - Artikel 1 des Gesetzes zur Regelung von Abscheidung, Transport und dauerhafter Speicherung von Kohlendioxid (Bundesrats-Drs. 282/09)
  - Einbringung als besonders eilbedürftige Vorlage gem. Art. 76 Abs. 2 Satz 4 GG (Aufnahme der Beratungen im Bundestag vor Abschluss des ersten Bundesratsdurchgangs)
  - zahlreiche Änderungsvorschläge des Bundesrates zum Regierungsentwurf (Bundesrats-Drs. 282/09 [Beschluss])
  - nachdem auch die Ausschussberatungen im Bundestag weit fortgeschritten waren, wurde am 24. Juni 2009 entschieden, den Gesetzentwurf in der 16. Wahlperiode nicht mehr abschließend zu beraten
  - Koalitionsvereinbarung für die 17. Wahlperiode: „zeitnahe“ Umsetzung der CCS-Richtlinie

Seite 3

Developing a legal framework for CCS technologies in Germany

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Bundesministerium
für Wirtschaft
und Technologie

Economic and environmental issues

Geothermie / CO_2-Endlager?

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Die Entwicklung des Weltklimas erfordert ein aktives Handeln. Daraus ergibt sich auch die Bedeutung, welche die CO_2-Speicherung hat, denn trotz intensiver Förderung von Technologien für erneuerbare Energien, sind diese im Energiemix nach wie vor nur ein Baustein neben den fossilen Brennstoffen - den hauptsächlichen CO_2-Produzenten. Das Kraftwerk Jänschwalde benötigt zum Beispiel bei Volllast ca. 80.000 t Braunkohle / Tag, was einen CO_2-Ausstoß von rund 75.000 t zur Folge hat. Der Anteil Deutschlands an den weltweiten CO_2-Emissionen beträgt drei Prozent.

Die CCS-Technologie bringt uns dem Ziel einer klimaneutraleren Energiegewinnung näher. Deutschland und besonders die Hauptstadtregion Berlin/ Brandenburg nehmen dabei eine Vorreiterrolle ein. Die Einführung der CCS-Technik wird in der EU gefördert. Daneben werden die kostenintensiven Techniken von der Industrie finanziert, die für ihre Investitionen Planungs- und Rechtssicherheit benötigen. Berlin-Brandenburg ist mit seiner Forschung auf diesem Gebiet ganz weit vorn, dazu gehört auch das GFZ Potsdam und die TU Berlin.

Das unterirdische Lager in Ketzin, wo bereits CO_2 in den Erdboden eingebracht wurde, ist ein reines Forschungslabor für die CSS-Technologie. Was wir in den Laboren der Universitäten entwickelt haben, ist heute eine großtechnische Kraftwerksanlage geworden - die Oxyfuel-Anlage in Brandenburg "Schwarze Pumpe". In dieser Kraftwerks-Pilotanlage wird das CO_2 bereits im Verstromungsprozess abgeschieden und soll unterirdisch gespeichert werden, so dass es nicht erst in die Atmosphäre gelangt. Die Anlage finanziert und betreibt Vattenfall.

Ein aktueller Konflikt CCS / Geothermie ist mir derzeit nicht bekannt. Die porösen Sandsteinschichten, die zur CO_2-Speicherung genutzt werden, liegen in einer Tiefe von 1.000 bis 2.000 m und darunter. Der Häuslebauer, dessen Erdwärmepumpe nicht tiefer als maximal 100 bis 200 m reicht, ist somit nicht von einem Nutzungskonflikt betroffen. Die industrielle Nutzung, also Erdwärme für den Betrieb von Kraftwerken, beginnt erst in Tiefen von 3.000 bis 4.000 m, weil dort die sehr hohen Temperaturen herrschen. Diese Felder liegen wiederum unter den geplanten CO_2-Speichern. Die heutige Bohrtechnik durchörtert die sich überlagernden Schichten. Man kann gefahrlos auch durch ein CO_2-Lager bohren, hin zu den tiefen geothermischen Quellen. Für mich steht fest, Forschung und die daraus folgenden technischen Entwicklungen gehen weiter, der Energiemix wird sich fortsetzen und es geht nur gemeinsam.

Future strategies of an energy company combating climate change – CCS accompanied by renewable energy sources

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Climate change is one of the greatest environmental challenges of our time. Being an energy company means that Vattenfall is part of the problem, but also that Vattenfall is part of the solution.

Electricity generation remains the primary application for coal. Increasing efficiency is a necessary way to lower CO_2 emissions, but this alone will not be enough to reduce or even eliminate the negative impact of fossil fuels. According to leading climate and energy research authorities such as the IPCC and the IEA, necessary and substantially greater CO_2 emissions reductions from fossil fuels can only be achieved via Carbon Capture and Storage (CCS).

As one of the technological frontrunners, Vattenfall Europe has invested more than € 70 million in the erection and the operation of the world's first lignite-fired power plant featuring oxyfuel technology. This 30 MW_{th} pilot plant in Schwarze Pumpe commenced operation in 2008 and provides vital information regarding CCS technology and development of new innovative design components. The Vattenfall project demonstrates that technologies ready to enter commercial operation by 2020 are already in motion. However, a phase of upscaling is necessary to improve technology optimization and implementation in order to eliminate existing drawbacks, such as the relatively high energy consumption of CCS components.

The CO_2 from the German CCS plants will be transported to appropriate storage sites primarily via pipelines. Potential storage sites like the ones in Birkholz, in Neutrebbin or the gas field Altmark still need to be further explored and certified so that secure and sufficient storage capacities might be developed in due time to enable energy providers to "close" the CCS technology chain. CCS will thus build the necessary bridge towards the approaching age of renewables.

Vattenfalls ambitions regarding reduction of CO_2 emissions are not only focused on CCS. There is also a strong engagement to broaden the company's future energy mix. Renewable energy sources such as biomass heating power plants, on- and off-shore wind farms, photovoltaic systems or run-of-river plants are developed further towards higher economic efficiency. The usage of geothermal energy might be another element for implementing this strategy.

The systematic and objective exploration of the geological underground is an essential prerequisite for optimizing resource allocation including geothermal potentials and CO_2-storage capacities. Accompanied by research and industry projects on a demonstration scale as well as a defined legal framework the optimal path for a future socially accepted usage of geological formations might be developed in a context of sustainable and safe energy supply.

Carbon Capture and Storage: Eine Technologie für Klimaschutz und Versorgungssicherheit

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Europa und Deutschland setzen auf Klimaschutz und Reduzierung von CO_2-Emissionen

- Treibhausgasemissionen, darunter insbesondere Kohlendioxid (CO_2), führen zu einer immer stärkeren Erwärmung der Atmosphäre.
- Europa hat sich zum Ziel gesetzt, CO_2-Emissionen drastisch zu reduzieren.
- Deutschland hat sich verpflichtet, diese Ziele zu erfüllen.
- Bei der Verstromung von fossilen Energieträgern - wie Braun- und Steinkohle - entstehen hohe CO_2-Emissionen.
- Alle innovative Technologien - darunter auch die CCS-Technologie - können dabei helfen, den CO_2-Ausstoss in die Atmosphäre zu vermeiden.

Internationale Aspekte zum Klimawandel

- Der Klimagipfel in Kopenhagen hat viele Erwartungen enttäuscht. Mit der Vertagung und dem Fehlen verbindlicher Verpflichtungen werden die Anforderungen an die zukünftig notwenigen CO_2-Reduktionen zwangläufig steigen, wenn das "2-Grad-Ziel" bis 2050 erreicht werden soll.
- IPCC: Senkung der weltweiten CO_2-Emissionen bis zum Jahr 2050 um 50 bis 85 Prozent (Ausgangsjahr: 2000) notwendig
    - Annex-I Länder 14.4 Mrd. t (2000)
    - Nicht-Annex-I Länder 9,7 Mrd. t (2000)
- Industrieländer bisher hauptverantwortlich für weltweite CO_2-Emissionen
- CO_2-Emissionen in den Entwicklungs- und Schwellenländer werden weiter steigen (Steigerung: Bevölkerung, Wohlstand, Energieintensität)
    - Annex-I Länder 14,7 Mrd. t (2008)
    - Nicht-Annex-I Länder 15,4 Mrd. t (2008)

Schlussfolgerungen

- Selbst bei einer Reduzierung der Emissionen in den Annex-I-Ländern auf „Null“ kann das „schwächere“ 50 %-Ziel nicht erreicht werden.
- Entwicklungs- und Schwellenländer müssen sich im erheblichen Umfang an Emissionsreduktion beteiligen.
- Industrieländer müssen Vorreiterrolle einnehmen und erheblichen materiellen Beitrag leisten:
    - Hauptverursacher
    - Ungleiche Verteilung der Wirtschaftskraft

Renewables first

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Long-term perspective

The long term energy supply in Germany, Europe and worldwide must be secured almost completely without the use of fossil fuels and resources. Our non-renewable resource quantities will be exhausted, today's underground formations advised for CO_2 savings will be filled and – in best case – we will no longer depend on fossil resources because the International community succeeded making worldwide energy production and -consumption more sustainable due to an integrative and effective climate protection regime which reduced CO_2 emissions drastically.

Sustainable ways of reducing CO_2 emissions

In order to limit global warming to 2°C maximum rise the Industrial Countries need to reduce their CO_2 emissions below 80% until 2050. For Germany this implies almost total decarbonisation. Sustainable possibilities of CO_2 reduction are saving energy, higher energy efficiency and the use of renewable energy forms.

Even under not yet existing requirements, CCS would be economically applicable if it was generally understood as a temporary solution – based on the fact that underground storage capacities are of finite dimension.

Consequently, any use of underground formations for ecological energy use, extraction and storage would be more sensible regarding climate and energy political issues than storage and final disposal of residual materials. It also needs to be favoured from a legal perspective, in order not to restrain other more sustainable and economical techniques that are more supportive in terms of climate protection and security of energy supply.

Economical and ecological aspects

According to today's level of knowledge and research the use of CCS-technology bears high risks in both – economical and ecological regards.

Worldwide there is no sufficient experience data regarding long-term storage of CO_2 in saline aquifers, which are the theoretically concerned storage facilities in this case; the tectonic specifics or possible incidents are largely unexplored and our knowledge about spreading or reaction behaviour in deep geological layers is limited.

Taking this into consideration, questions concerning the impact on ground water, the possibility and danger of lingering or sudden leakage are not satisfactorily answered.

In addition the adoption of CCS in energy extraction from coal is currently not presentable due to several cost intensive factors such as the decrease of efficiency , increase of resource demand, the not yet numbered costs for transportation, swaging and securing of storage facilities and last but not least the social resistance arising from a lack of acceptance for this technology.

Likewise the application of geothermal energy has a high need of research and development. Investments in this area of energy production are highly sustainable due to the potential of this energy source.

Geologische CO_2-Speicherung und tiefe Geothermie im Kontext anderer Nutzungskonkurrenzen

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Der unterirdische Speicherraum in Deutschland ist begrenzt. Er wird bereits seit vielen Jahrzehnten beispielsweise durch den klassischen Bergbau auf Kohle, Salz, Erdöl und Erdgas und damit verbundene Eingriffe inklusiv der Reinjektion von Produktionswässern (aus Erdöl- und Erdgasförderung) und Laugen (aus der Veredelung des Rohsalzes) beansprucht. Seit einigen Jahrzehnten werden aus strategischen Gründen der Rohstoffversorgung Erdöl und Erdgas im Untergrund gespeichert. Unterirdische Hohlräume werden zu Deponierung gefasster toxischer oder radioaktiver Abfälle genutzt. Die Gewinnung geothermischer Energie aus dem tiefen Untergrund wird infolge der hohen Preise konventioneller Energierohstoffe zunehmend interessant. Zukünftig wird man sicherlich auch die Speicherung erneuerbarer Energien – in Form von Wasser, Druckluft oder Wasserstoff – in diese Reihe der Nutzungskonkurrenzen einordnen müssen.

Bei künftigen Planungen von CO2-Speichern oder Bohrungen zur Gewinnung tiefer Geothermie sind (1.) Nutzungskonkurrenzen zu beachten, (2.) mögliche Synergien zu finden und einzusetzen sowie (3.) auch ggf. Prioritäten bei der Nutzung zu setzen.