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ScienceDirect

Energy Procedia 40 (2013) 249 – 255

Energy Procedia

European Geosciences Union General Assembly 2013, EGU

Division Energy, Resources & the Environment, ERE

Research On Utilization Of Geo-Energy

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Abstract

The world's energy demand will increase year by year and we have to search for alternative energy resources. New concepts concerning the energy production from geo-resources have to be provided and developed. The joint project GeoEn combines research on the four core themes Geothermal Energy, Shale Gas, CO_2 Capture and Utilization and CO_2 Storage. The research is carried out in the federal state *Brandenburg* in Germany where all project partners - Helmholtz Centre Potsdam, University of Potsdam, Brandenburg University of Technology - and the infrastructures - Schwarze Pumpe, Ketzin, Groß Schönebeck - are located.

Keywords: Geo-energy; geo-resources; CCS technology; CO_2 capture; CO_2 storage; shale gas; geothermal energy

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doi:10.1016/j.egypro.2013.08.029

1. Introduction

The research in the joint research project GeoEn concentrates on four core themes, which are relevant for the energy production of fossil and renewable geo-resources. Technologies and solutions for the prevention of the climate hazardous greenhouse gas carbon dioxide (CO_2) are developed in the research fields CO_2 capture, utilization and transport (2.1) and CO_2 storage (2.2). Energy production from unconventional gas resources is studied in the research field shale gas (2.3). The use of renewable energies is the aim in the research field of geothermal energy (2.4).

The work on the mentioned core themes is carried out with a holistic research approach because of the complexity of geological systems. A wide spectrum of geo-scientific cross-cutting themes enables pure disciplinary research, where especially multidisciplinary works between the joined partners is required. We focus in particular on the cross-cutting themes reservoir exploration, exploitation and monitoring (3.1), utilization technologies and interactions (3.2) and modelling and simulation (3.3).

Further issues worked on in GeoEn are technology and knowledge transfer (4.1) and research on the determinants of acceptance of new technologies (4.2).

All publications related to the research in GeoEn can be found on the project internet page [1] (www.geoen.de), where the publication list is updated frequently. See also the published Special Volumes [2] and [3]. This paper presents the work of the GeoEn project members who contributed with textual basis and are not explicitly cited.

2. The four core themes in the GeoEn project

2.1. CO_2 capture, transport and utilization

In order to stop the existing critical heating of our planet, the emission of carbon dioxide (CO_2) into the atmosphere has to be severely reduced. In modern coal power plants the so-called CCS-technology (Carbon Capture and Storage) is used in order to reduce the CO_2 emission in the combustion process of fossil energy sources. It comprises the processes of capture, transport und the CO_2 storage in the underground to avoid the emissions of the climate-damaging CO_2 into the atmosphere.

Several processes of CO_2 capture are examined, like pre- and post-combustion. Focus on the energy research within GeoEn is the Oxyfuel technology. The combustion in this Oxyfuel process is made with pure oxygen instead of ambient air. The flue gas is enriched with the climate-damaging CO_2. The amount of CO_2 in the flue gas is nearly 90% which is subsequently processed further or stored. The first power plant with Oxyfuel technology was built and runs at the site Schwarze Pumpe, Brandenburg, Germany.

The research focus within GeoEn is on the Oxyfuel process and its technical marketability. For alternative combustion processes (pre- and post-combustion) optimal solutions should be found as well as for a low-priced oxygen supply. Processes like the drying and the gasification of coal to increase the efficiency of fossil based power plants are examined. A special attention is paid to novel energy conversion processes. The goal is to create a model for the whole CCS process chain. Therefore the specific physical, chemical and thermodynamic processes are simulated and several process stages are investigated.

The utilization of CO_2 as raw material is another important component of research in GeoEn. The goal is to produce methane by using carbon dioxide. Carbon dioxide in almost pure form is the product of the Oxyfuel-combustion of lignite. At moderate temperatures of around 350°C, hydrogenation to methane is possible via the Sabatier reaction $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. Beside CO_2 capture and storage this alternative opens a new perspective in terms of utilization. The CO_2 is transferred into methane (CH_4), an energy source, for which an extensive infrastructure already exists. Thus feeding of this CH_4 into the

existing gas distribution system is possible. The hydrogen necessary for the Sabatier conversion is produced utilizing excess energy from regenerative sources. Thus it opens the possibility of energy storage. The advantages of storing methane over storing the energetically higher hydrogen lies in the better transportability of methane on one hand and the utilization of CO_2 on the other hand.

The development of cheap catalysts and systems of catalysts for the Sabatier reaction, with a small content of noble metals is of special interest. A further criterion is the special application of catalysts for the conversion of CO_2, emitted in the course of the Oxyfuel process. Concepts of reactor and catalyst design will be tested and the conditions for industrial application will be evaluated. This includes the investigation of cross sensitivities against typical contaminations in the Oxyfuel gas and the investigation of catalyst recycling.

2.2. CO_2 storage

In respect to the global development of a renewable energy supply, in the following decades the energy supply will still be dominated by fossil fuel power plants. Therefore modern power plants should be operated and the emitted CO_2 should be captured, safely transported and stored. To slow down the increase of CO_2 the storage of great amounts of CO_2 can be envisaged as a bridge technology during the transfer to an energy supply which is decreasingly based on the combustion of fossil fuels.

Suitable reservoir and cap rocks have to be identified and examined for a safe long-term storage of CO_2. In the framework of the project GeoEn a worldwide unique chance adds up to examine the whole process chain of capture technologies to the storage in saline aquifers and depleted natural gas fields.

At the CO_2 storage pilot site Ketzin CO_2 is injected in a saline aquifer since June 2008. The research focusses in the geological storage and the processes of underground CO_2 injection and migration.

The GeoEn project goals are the development of innovative exploration technologies and efficient drilling and reservoir technologies, the definition of safety relevant standards as well as the monitoring of the CO_2 expansion in the reservoir and the modelling of the dynamic processes in CO_2 storage sites. Thus we have the unique possibility to determine and balance qualitatively and quantitatively the utilization conflict as well as the synergies in the combined usage of the underground (CO_2 storage and geothermal energy, integrated process chain shale gas – CO_2 storage) through the cross-linking with other core topics in the project.

2.3. Shale gas

More than 70% of the conventional gas reserves occur in Western Siberia and the Middle East. This amount can satisfy the global demand for the next decades considering the current demand.

Shale gas is already an established energy source in the U.S.A. and contributes to more than 12 per cent to the domestic U.S. gas production. Shale gas may also be an alternative, locally available resource in Europe and -in the case of successful exploration- may prevent supply shortfall.

Conventional oil and gas fields are sourced by fine-grained siliciclastic or carbonate rocks both rich in organic matter. In such conventional scenarios the released fluids are trapped in porous and permeable reservoir rocks overlain by impermeable cap rocks. In contrast, shale gas systems differ in important aspects. Shales represent all three different elements: source rock, reservoir rock and cap rock. However, many open questions still offer space for detailed research, e.g., in terms of the individual geological development and shale gas controlling factors.

Currently shale gas is exclusively exploited in North America. But all successful U.S. shale gas systems differ, e.g., in age of the shale, mineralogical composition, etc. Moreover, each sedimentary basin underwent an individual history controlled by different factors. The burial histories of sedimentary basins

vary, can cause thermogenic shale gas formation, but also gas formation from biogenic activity is a known phenomenon. Thus, no single and no generally accepted “prototype" of a shale gas system exists. Due to this variability it is our primary aim to focus our research activities on the resolution of those factors which control shale gas formation and preservation in time and space.

GeoEn research about shale gas focusses on processes which control shale gas formation. The approach includes research on domestic black shales with proven source rock potential together with the development of exploitation strategies. In this context local and accessible gas resources shall be determined, which have the potential to buffer the increasing domestic energy demand.

The analysis of shale gas relevant processes in Northeast Germany with methods of basin analysis are complemented by analysis of shale gas relevant organic-inorganic interactions at the nanoscale.

It is the long-term aim to establish an economically, environmentally compatible and sustainable shale gas exploitation. Against this background we are active in the fields of geophysical exploration, drilling engineering, feasibility studies and reservoir geology.

In the GeoEn project a strong focus is on environmental issues and the transfer of knowledge and information to the public. The developed internet information site SHIP Shale Gas Information Platform (http://www.shale-gas-information-platform.org) is engaging in the public discussion of technical and environmental issues related to shale gas exploration and production.

2.4. Geothermal energy

Geothermal energy is a widely accepted renewable source of energy with a lot of advantages. It is a domestic and therefore crisis-proof and base-load compatible energy source: geothermal plants can provide environmental friendly heat or chill and power at all times. However, geothermal technologies have to be further developed, in order to increase the planning reliability and a sufficient efficiency in the plant operation.

Further research is needed especially in the reservoir exploration and exploitation of deep geothermal heat sources. Optimization and the increase of efficiency of plant components at the surface have to be achieved in order to provide an industrial production. Newly developed system solutions for a crisis-proof domestic power supply have economic advantages: the competition for the domestic industry will be improved and new jobs are created.

The research can profit of a large-scale in-situ lab, the geothermal research power plant Groß Schönebeck. Its thermal water circulation uses two more than four kilometres deep research wells. All necessary system components of the geothermal equipment are tested and recommendations for their qualification are worked out at this pilot site during operation.

A new online fluid monitoring system (FluMo) has been developed, which allows measurements of physical-chemical parameters during production. Together with work on thermal rock properties, thermal modelling and corrosion studies this contributes to raise the feasibility of geothermal energy production. An accompanying microbiological monitoring, as well as examinations of the geothermal fluid and its interaction with the plant components in terms of occurring scalings and their radioactive components is carried out.

3. The three cross-cutting themes in the GeoEn project

3.1. Reservoir exploration, exploitation and monitoring

This field of research includes exploration, exploitation and monitoring of reservoirs. Therefore it is the cross-cutting theme for the three geo-scientific core issues in the GeoEn project: CO_2 storage, shale

gas and geothermal energy. The work packages attend to a wide spectrum of time scales from geological periods to the examination of changes in the reservoirs while in use. In the same way the considered special scales reach from the analysis of sedimentary basins to microscopic examinations of rock and fluid samples. The results of those investigations contribute to the better understanding of reservoir types and the processes which take place within those reservoirs. Related methods applied for that purpose include: basin analysis, analysis of controlling factors of shale gas formation, the determination of thermo-dynamical, hydraulic, biological, chemical and kinetic reservoir characteristics, the geophysical reservoir exploration (reflection seismic, geoelectric and CSMT – controlled-source magnetotellurics), several monitoring methods (e.g. distributed temperature measurements in wells during production) and examinations of geomechanics and well stability.

3.2. Utilization technologies and interactions

The research in this cross-cutting issue deals with the implementation of research results into utilization technologies. The attained knowledge and data are to be processed effectively. Besides the basic research the technical implementation is to be done and accounted for in all work packages. For this reason the work packages of CO_2 capture, transport and utilization are directly linked to each other. Geothermal energy, CO_2 storage and the production of shale gas access the resource “deep underground”. Knowledge attained in every section of the GeoEn project will be a benefit to all the other core topics. Especially the two core topics geothermal energy and CO_2 storage use nearly the same drilling techniques and go back to the data of the underground properties. Accordingly, the co-operation within GeoEn produces noticeable synergy effects. In particular, the heat transport process is relevant for geothermal utilization and for the CO_2 process chain (injection) are basically the same which offers another possibility for complementary work. Similarly the artificial creation of higher permeable reservoir areas with “hydraulic fracturing” is important in the fields of geothermal energy as well as of shale gas.

3.3. Modelling and simulation

This work package includes different aspects of process modelling which are relevant for processes during CO_2 capture, transport and utilization and for the evaluation of the potential use of reservoirs. Numerical simulations of the coupled processes are required for a large range of scales from regional scale over reservoir scale to scales of fluid flow processes in the CCS process chain. These models need to be validated by basic observational data, as the knowledge of the physical properties and of the underground and its behaviour is essential for the exploration of suitable areas for CO_2 storage, shale gas or geothermal resources as well as for the implementation of the CO_2 process chain. All these applications call for a process understanding on how fluid flow, heat transfer, mass transport, chemical reactions and mechanical deformation influence the CO_2 process chain and the reservoir. In terms of the validation and optimization of the operating sequences, the results of the numerical simulations of CO_2 transport are implemented into the design of the process chain. An important factor in this case is the time frame of the on-going processes. The economically and ecologically reasonable utilization of reservoirs cannot be based on real-time experiments only, as the latter would require to long time periods. Therefore, the three-dimensional simulation of those natural processes still is key, though these simulations pose great challenges to the methodical development. Accordingly this research field focuses on the development of numerical simulation methods and the creation of regional 3D models and their use for the prediction in exploration and utilization of reservoirs.

4. Supplementary issues

4.1. Technology transfer

The issue technology and knowledge transfer includes themes like international technology transfer, conclusions for the technology transfer from the economic analysis of every work package in the GeoEn project, the compilation of specific framework conditions and market information, the organization of network meetings between science and economy, the formulation of a proposal profile (science and economy) for the relevant future markets, the approach and public relations to relevant institutions in the targeting markets including the preparation and participations in travels to the relevant regions and participation in fairs.

4.2. Acceptance of new technologies

In the context of geo-energy the public acceptance of modern technologies is very important, in order to implement the technologies in practice. Questions are worked on which arise in the forefront of CO_2 capture, transport and storage technologies, energy source production from shale gas and energy production from geothermal reservoirs in the framework of technological impact assessment, technological assessment and the refusal of acceptance. Questions addressed here include: Does a newly developed technology fit in the existing organizational shell (at local, national or international level)? Are the developing interactions (political, organizational, structural) still controllable?

The research focusses on the technical-theoretical and ethical discussion of the factors of technology acceptance.

5. Conclusion

In the GeoEn project the four core themes - CO_2 capture, utilization and transport, CO_2 storage, shale gas and geothermal energy - are not regarded competitively, but the synergies between them are used. The new approach of linking the scientific research over the cross-cutting themes is a real profit and generated good effects on the communication and co-operation between the scientists and the institutions.

Acknowledgements

The project GeoEn is funded in the framework "Spitzenforschung und Innovation in den neuen Ländern" by Bundesministerium für Bildung und Forschung (BMBF), Grant no. 03G0767A-C.

The GeoEn Group are: M. Mutti, U. Hammes, H.-M. Schulz, D. Kerschke, B. Horsfield, W. Mierke, A. Hübner, I. Kapp, A. Förster, S. Fuchs, A. Liebscher, S. Fischer, O. Ritter, M. Weber, R. Streich, M. K. Bhatt, M. Baumann, C. Schmidt-Hattenberger, R. Giese, P. Bergmann, G. Dresen, E. Rybacki, T. Meier, M. Makasi, H. J. Krautz, M. Klatt, D. Seifert, R. Abang, M. Nimtz, T. Kangwanpongpan, P. Gorenz, D. Schmeisser, K. Müller, C. Das, J. Erzinger, F. Wilke, M. Vasquez, E. Huenges, A. Saadat, S. Regenspurg, H. Francke, M. Thorade, T. Reinsch, J. Henninges, B. Viehweger, W. Garkas, H. Würdemann, D. Morozova, D. Neumann, J. Weigt, J. Kallmeyer, M. Alawi, R.R. Adhikari, P. Sauer, A. Kitte, M. Cacace,

V. Noack, B.-O. Kaiser, Y. Cherubini, A. Liebscher, B. Wiese, M. Kühn, Ch. Egbers, N. Herzog, A. Shahirpour, H. Schmidt, F. Schulz, C. Glawe, W. Dransch, P. Burgess, A. Rudloff, K. Kornwachs, W. Zimmerli, M. Harz, A. Vesper.

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