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ENhanced Geothermal Innovative Network for Europe

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ABSTRACT
The European Commission support for geothermal energy research has been constant since the end of the eighties and has significantly increased within its 6th R&D Framework Program. The ENGINE Coordination Action (ENhanced Geothermal Innovative Network for Europe) is aimed at co-ordinating present R&D initiatives for Enhanced Geothermal Systems (EGS), ranging from the resource investigation and assessment stage through to exploitation monitoring. Thirty five partners are involved in ENGINE, representing 15 European Countries plus Mexico, El Salvador and Philippines. By mid-term, the project has organised 2 conferences and 3 specialised workshops. Materials available on the web site http://engine.brgm.fr already show the work that has been completed revealing a strong motivation of the scientific community for updating the framework of activities, preparing a Best Practice Handbook and defining new ambitious research projects.

1. INTRODUCTION

The contribution of geothermal energy is a key factor to the successful achievement of the objectives of the European Commission concerning the development of renewable and sustainable energy.
The European Commission support for geothermal energy research has been constant since the end of the eighties and has significantly increased in the 6th Framework Program as several projects are directly related to the development of EGS (Schuppers, 2006). The ENGINE project (ENhanced Geothermal Innovative Network for Europe) is a Co-ordination Action that started in November 2005. Its main objective is to co-ordinate present Research and Development initiatives for Unconventional Geothermal Resources and in particular Enhanced Geothermal Systems (EGS), ranging from the resource investigation and assessment stage through to exploitation monitoring. It is meant to complement other Framework Programme instruments in contributing toward integrating research in Europe through well-planned networking or co-ordination activities. Two Specific Target Research Projects are dedicated to the Hot Dry Rock Project at Soultz-sous-Forêts (Fritsch and Gerard, 2006) and to the development of an innovative geothermal exploration approach based on advanced geophysical methods (the I-GET Project, Bruhn et al., 2006). Other on-going EGS projects like Gross Schonebeck (Germany, Huenges et al., 2006), Basel (Switzerland, Hopkirk and Haring, 2006) and Cooper Basin (Australia) provide valuable experience input to the ENGINE Co-ordination Action. ENGINE is also deeply connected to the HITI STREP dedicated to high temperature tools for investigating supercritical fluids as well as high temperature reservoir conditions (Asmundsson, 2007). To complete this screening of the 6th Framework Program, the LOW-BIN project aims in improving cost-effectiveness, competitiveness and market penetration of geothermal electricity generation schemes (Karytsas and Mendrinos, 2006). In addition, international co-operation takes place through the Commission participation in the IEA Geothermal Implementing Agreement.

2. OBJECTIVES OF THE PROJECT

The proposed Co-ordination Action is aimed at providing an integration of activities related to geothermal energy in Europe, and compiling recommendations from expert groups into a European Reference Manual for the development of Unconventional Geothermal Resources and in particular Enhanced Geothermal Systems. The Co-ordination Action will thus contribute to these society and policy objectives by:

- identifying the gaps and barriers holding back geothermal-energy development (environmental impacts, policy/law/regulatory barriers, etc.) and proposing actions to overcome the bottlenecks (research projects, expert studies, information campaigns, promotion, etc.);
- establishing how Enhanced Geothermal Systems reservoirs can be developed under various site specific conditions and that geothermal energy can be considered as a source of energy potentially available throughout Europe;
- defining economic conditions for a reassessment of the profitability of geothermal energy in the framework of "Unconventional Geothermal Resources "; and in particular how geothermal energy can contribute, in the new candidate countries, to their heat and electricity production;
- illustrating how a healthy geothermal energy industry can assist the energy self-sufficiency of Europe and promote the development of local industrial capability;
- proposing a complete economic approach towards geothermal energy, taking into account the sustainability and the environmental benefits.

3. ORGANISATION OF THE ENGINE CO-ORDINATION ACTION

To promote an efficient network of geothermal activities, the Co-ordination Action define, organise and manage joint and common initiatives through:

- an Integration Phase, i.e. a bottom-up and federative strategy aimed at providing an updated framework of activities concerning geothermal energy in Europe and developing motivation within the scientific and technical community by exchanging experiences and sharing practices. It covers all initiatives and bottlenecks encountered during the Investigation of EGS and Unconventional

Geothermal Resources, drilling, stimulation and reservoir assessment and Exploitation, economic, environmental and social impact. Workshops and conferences are regularly organised in this framework.

- a Synthesis Phase; i.e. an expertise strategy for defining the best practices and priorities for research investment. The expert groups will perform specific studies and strengthen links between the geothermal community and financial and political institutions.

4. AN UPDATED FRAMEWORK OF ACTIVITIES AND NEW PROJECTS FOR THE DEVELOPMENT OF EGS

Preliminary integration resulting from the bottom-up and federative strategy concerning Defining, exploring, imaging and assessing reservoirs for potential heat exchange (Bruhn and Manzella, 2007), Stimulation of reservoir and microseismicity (Huenges and Kohl, 2007), Environmental impacts by the use of geothermal energy (Frick and Kaltschmitt, 2007), Electricity generation from EGS (Le Bel and Kaltschmitt, 2007), reveal a strong motivation of the scientific community for updating the framework of activities and establishing a long term partnership with stakeholders and industry. This phase of integration will lead to the identification of bottlenecks and the evaluation of the priorities for defining new research projects (Schuppers, 2007).

4.1. Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems.

The synergy with the FP6 IGET project dedicated to Integrated Geophysical Exploration Technologies proved to be fruitful since the kick off meetings. This project is aimed at developing an innovative geothermal exploration approach based on advanced geophysical methods and consists in improving the detection, prior to drilling, of fluid bearing zones in naturally and/or artificially fractured geothermal reservoirs. The ENGINE coordination has dedicated a workshop in Potsdam in November 2006 to the identification of the parameters that are needed before exploration drilling within potential geothermal reservoirs. It was agreed that structural geology, temperature distribution, stress and fluid pathways, as well as the chemical and mineralogical composition of the rocks hosting the geothermal system, constitute key elements that can be considered as priorities in terms of research needs.

Structural Geology is fundamental for imaging potential geothermal reservoirs. Geophysical methods are suitable for determining the architecture, geometry, and quality of the target intervals. However, existing methods must be improved and used in combination with different, highly sensitive techniques (passive and active seismics, MT, etc.) in order to meet the specific requirements of modern geophysical exploration for geothermal purposes. A significant effort has to be made in the interpretation of geophysical features that must be supported and validated by both petrophysical laboratory and borehole measurements, as well as by modelling.

Finding heat at depth is a second challenge of the investigation phase. The extension of large-wavelength heat-flow anomalies at depth is often inaccurate due to insufficient knowledge of the causes of the heat-flow anomaly and of the thermal properties of the main lithologies. Several physical parameters are coupled with temperature and can be imaged by different geological, geophysical and geochemical methods. Thus, the definition of possible targets for EGS could be improved by the use of a 3D modelling platform, in which all solutions from geological, geochemical and geophysical modelling, direct and inverse, could be combined and analysed.

The knowledge of the stress field is another parameter crucial for understanding and stimulating fluid circulation. The influence of the stress field on hydro-fracturing is observed while the mechanisms of rupture and propagation of an existing fault system and related displacement remain debated as well as the actual permeability associated with. The ability of the fault and fracture systems to channel fluids is directly dependant on the stress field (orientation and intensity). Favourable and unfavourable conditions exist depending on the tectonic setting and the geological environment.

In conclusion, defining integrated conceptual models is a next step for defining the necessary starting conditions for the development/stimulation of an EGS. There is a need to refer to conceptual models of the main geothermal sites, ranging from extended active geothermal sites through to EGS for which heat distribution and permeability networks are available for modelling pathways for fluid circulation, gas-water-rock interaction processes and heat exchange. A significant improvement of knowledge is expected from natural analogues on which hypotheses could be tested, for example circulation of fluids in relation to seismicity and lithology heterogeneity, or the thermal imprint of fluid circulation. The links with other investigation programmes, such as nuclear waste storage, capture and geological storage of CO_2 and oil and gas field development, could be also developed as a way to benefit from existing installations and experiences.

4.2. Drilling, stimulation and reservoir assessment

The main focus has been on the enhancement methods during the first year. Enhancing or engineering the reservoir is a key issue for EGS and mechanical and chemical stimulations are commonly used to enhance their hydraulic properties. Moreover, induced microseismicity, geochemical tracing and thermal evolution of the system is an exceptional opportunity to characterize the reservoir and its dynamics (Mégel et al., 2006; Sanjuan et al., 2006). Nowadays the success of these experiences is still a matter of trial and error, depending on the variety of geological contexts and site conditions. More detailed reviews have been planned about some stimulation methods, and exchanges with hydrocarbon industry and underground nuclear waste and CO2 storage platforms are encouraged. As it is already partly expressed in the FP7 work program, researches should (a) define conceptual models for irreversible enhancement of permeability of the reservoirs (relationships between stress field and strain mechanisms, fluid-rock interaction, fluid pressure development…), (b) analyse the distribution in time and space of the magnitude of seismic events in order to improve the 3D imaging of the fracture system and stress field (interaction between tectonic, lithostatic and fluid pressure), (c) set requirements for seismic monitoring (modelling and metrology) and recommend management

strategies for prolonged field operation, and (d) provide a methodology for the estimation of site-specific seismic hazard prior to development of potential sites for EGS. Finally, the induced earthquake in Basel on the 8th December reveals the urgent necessity to fill the gap in knowledge about this matter. An innovative project dedicated to the role of induced seismicity in EGS has been prepared following the 1st call for proposal of the 7th FP and is considered as a spin-off project from ENGINE.

4.3. Economic, environmental and social impacts

The definition of an area thermally suitable for the development of an EGS is also highly depending of the exploitation and business plan including an evaluation of the economic, environmental and social impacts. One of the R&D perspectives related to this aspect is to analyse and assess possibilities and limitations of the currently available power plant technology using the energy retrieved from low enthalpy geothermal sources. To get an overall view, representatives of research and industry as well as project operators and planners have been brought together during a workshop and extended during a meeting of the Stakeholders committee. Besides some partly controversially conducted discussions, the basis for fruitful exchange of information and experiences was thus created. The available know-how from existing geothermal power plants shows that electricity production from low enthalpy resources in Europe is still a fairly young technology which lacks wide experience. Nevertheless there are quite a lot of projects planned and considerably more experience will be available in the years to come.

The discussion about the pros and cons of ORC vs. Kalina cycle, of air vs. water cooling, of fancy vs. proven technology and of power vs. Combined Heat Power is of no interest in terms of a further development of geothermal energy use. The main task of project developers is considered to be the identification of the optimisation potential in terms of the design of the working fluid, the cycle and turbine designs as well as the cooling systems. New and innovative technology is always connected with technical and financial risks. With an increasing technical effort and innovative ideas, the efficiency of a power plant cycle can be improved. Before being able to break into the market these technologies need to be tested, which is generally not possible on a purely commercial basis. Here the governments, national agencies and Europe are asked to support the market access of such new and innovative technologies which are definitely needed for further establishing geothermal electricity production in Europe. Both these concepts developed within the ENGINE action have been directly applied by choosing a Turboden-Cryostar binary power plant for the Soultz-sous-Forêts experiment (Gérard et al., 2006).

Another approach to promote geothermal electricity production from low enthalpy resources was stated as a combination with other sources of energy. New concepts of combining different energy options supplying heat on different temperature levels can result in a higher overall efficiency and thus profitability and hence be decisive for realising geothermal based electricity production.

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