ENGINE Coordination Action
(ENhanced Geothermal Innovative Network for Europe)

PROPOSITIONS

for the definition of Research Areas on

ENHANCED GEOTHERMAL SYSTEMS

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Extending the resources far beyond a conventional use of geothermal fields requires the use of non-conventional methods for exploring, developing and exploiting resources that are not economically viable by conventional methods. The **Enhanced Geothermal Systems** (EGS) concept covers specifically reservoirs at depth that must be engineered to improve hydraulic performance.

Promoting most appropriate practices and filling the gaps in knowledge

During more than 2 years, Enhanced Geothermal Innovative Network for Europe (ENGINE), a Coordination Action of the 6th Framework Program, has co-ordinated ongoing research and promoted the development and uptake of new technologies. Conferences and dedicated workshops have strengthened the collaboration between research teams and developed links with stakeholders, industry, international organisations… The results, available on the website at http://engine.brgm.fr presented during the final conference hold in Vilnius, Lithuania (12-15 February 2008), marks a milestone in EGS development towards its ultimate goal, i.e. the development of a technology to produce electricity and/or heat from the internal heat of the Earth in an economically viable manner, independent of site conditions.

Following up this coordination action, a program is now needed to demonstrate that EGS reservoirs with the required characteristics (well distributed, sufficiently large heat exchange surfaces, sufficiently high flowrate and temperature, low flow impedance, low water loss) constitute a sustainable source of energy at a price competitive with other renewable energy technologies. This demonstration should also define a strategy for upscaling EGS output to several 100 MWt and/or several 10 MWe. Priorities are defined towards the perspective of such a demonstration programme.

Defining priorities in the field of medium to long term research investment

Lessons learned from the Soultz EGS experiment, the sustainable development of the Larderello field in Italy, and the Icelandic geothermal power network, among other case histories, highlight the importance for coordinated research for technology improvement and for a continued reduction in cost through R&D developments. EGS are geothermal reservoirs with minimum temperatures of 85-100°C but that require artificial improvement of the hydraulic conductivity for economically viable produced flow rates. At each stage of EGS development proven methodologies can be applied and bottlenecks identified. From this state-of-the-art, priorities covering 4 main research areas have been defined in the field of medium to long term research investment:

Research area 1: Exploration, finding access to potential reservoir at depth

Exploration and investigation must identify closely the nature of geothermal heat concentrations and prospective reservoirs and to improve methods predicting reservoir performance/lifetime. Based on the past 50 years of exploration, *a priori* knowledge enables the definition of several prospective areas for EGS exploration in Europe. This definition of investigation targets does not raise major R&D barriers at a regional scale. The knowledge of the European lithosphere, collected information during ENGINE, recent surveys and reassessment of potential resources available in atlas and 3D models enable the identification of zones of interest for exploration. The following items still require R&D investment:

- Priority targets for EGS are deep potential reservoirs for which permeability could be enhanced through stimulation. A uniformed approach to identify such reservoirs and assess their geothermal potential at different depth underground is still needed. A significant step forward has been recently done for US in the framework of the MIT panel expert work: aimed at evaluating “The future of Geothermal Energy”. Such evaluation must be accomplished in Europe to be included in the Strategic Energy Plan. Compatible datasets, compilation and exchange of data are a prerequisite to build models predicting the distribution of heat at depth and should be one of the first action to be undertaken, with the support of the European geological Surveys and in compliance with the INSPIRE directive.

- Further exploration of EGS site must prove the presence of temperature higher than 85°C and the existence of rock permeability above a certain threshold either due to porosity in sediments or to fractures in crystalline and volcanic rocks. At the concessional scale, the geometry of the reservoir and its potential energy needs to be assessed and resolution remains rather low. Main gaps exist in combining in 3D geological, geochemical and geophysical data coming from different methods. Input from the IGET project is expected and should provide some advances in exploring the deep geothermal resources. Additionally, the stress conditions in the study area should be better known to enhance the flow conditions by hydraulic stimulation. This second action is complementing the first requirement concerning database and modelling.
- Review of case histories shows the importance of social acceptance and of the economic and environmental impacts of the EGS projects. The definition of new investigation sites must be accompanied by feasibility studies that must be formalised.

The main deliverables from this research area will be an assessment of the EGS potential of Europe and identification of about 20 potential sites of a demonstration program.

The final objective concerning exploration at the 2020 horizon is to improve the probability of successful EGS operation. Continuous efforts should lead to 90% successes with a 20% reduction of exploration costs for defining targets for exploration of EGS at the concessional scale. Improved and newly developed methodologies able to map and image in 3D temperature and permeability at higher resolution down to a depth of 10 km, and in particular at a depth of 2.5-3 km and the common use of a 3D modelling platform, as proposed in this Research area 1, are considered to be the main R&D challenges to reach this target. Development of innovative methodologies could also meet challenges for exploring new reservoirs in oil and gas industry and management of the underground especially for CO_2 sequestration.

Research area 2: Geothermal wells, improving drilling and completion technologies

The drilling into geothermal reservoirs requires most of the specific costs of geothermal energy provision. Drilling in shallow high temperature reservoirs is almost standardised and in deep high temperature reservoirs single experiences are made. Standard HC tools, reliable drilling mud systems, cementing technologies, and a set of casing completions are available for both environments. In hostile environment reliable completion is only available based on high cost casings.

An extended market penetration of geothermal energy requires that the drilling and completion costs must be cut by 20 to 30% by 2020. Further expansion of geothermal energy requires reliable technologies for deep reservoirs and equipment reliable under high temperature conditions during the overall drilling and completion technologies, with mitigated formation damage. In order to cut the drilling costs, drilling operations must become faster without loosing reliability. Improved performance requires facing new challenges. Shared know how and experiences must be supported by a new R&D project covering this research area. Stronger management of the overall drilling activities must be achieved including transport management, automatic pipe handling on drilling rigs, cementing at high temperature. Minimised infiltration of drilling mud into the reservoir constitutes another challenge. Low cost completion materials and new monitoring techniques down hole must also be available addressing strong hostile corrosive conditions during drilling and stimulation of the reservoir. The use of wire drill pipes while drilling can bring in real-time down hole information saving time for directional drilling or other related operations. These innovative approaches should be tested and implemented in the framework of an European demonstration program.

Research area 3: Reservoir engineering, stimulating the fluid flow underground

Reservoir engineering implies reservoir characterisation, production enhancement through stimulation techniques and assurance of the resource-sustainability. The characterization of the reservoir is achieved through assessment of reservoir parameters such as fracture and matrix properties, definition of reservoir boundaries and geometry. The enhancement methods require the application of specific technologies in different geoenvironments, including hydro-mechanical, acidization and thermal techniques. All tasks related to the engineering of the reservoir require a sophisticated modelling of the reservoir processes and interactions being able to predict reservoir behaviour with time and to minimize sensible micro-seismic impact.

An increase by a factor of 10 compared to the present achievements should be targeted in a 2020 perspective. Several tracks could be followed to achieve this goal. New visualization and measurement methodologies (imaging of borehole, permeability tomography, tracer technology, coiled tubing technology) should become available for the characterization of the reservoir. Standardized chemical and hydraulic stimulation technologies for all geo-environments need to be developed yielding reliable and reproducible results. In parallel new decision tools for modelling should be developed, namely for on-site support during test, integration of surface data for reservoir evaluation, design of optimum reservoir creation strategies, optimization of test duration and performance and multi-well layout planning.

In addition, in order to mitigate risks related to induced seismicity, conceptual models for irreversible enhancement of permeability of the reservoirs are needed in order to set requirements for seismic monitoring and recommend management strategies for prolonged field operation. Imaging fluid pathways induced by hydraulic stimulation treatments through innovative technology would constitute a major improvement of the Enhanced Geothermal Systems concept and provide decision support tools for seismic hazard mitigation.

Research area 4: Exploitation, Improving the efficiency

The exploitation activities include all technical equipment needed to provide heat and/or electricity from wells. This includes e.g. the production pump, the piping, the heat exchanger, the power plant and any auxiliary equipment. Technical equipment is available on the market. However, efficiency of the different system components can still be improved. This is especially true for low-enthalpy power plant cycles (e.g. ORC, Kalina Cycle), cooling systems, heat exchanger and production pumps for the brine. Integration of the different components within the overall system also needs to be optimized.

Several targets can be proposed taking into account recent improvement in technologies and the growing geothermal activity. The net electrical efficiency of the power plant cycle and of Combined Heat and Power systems should be improved till 2020 by 20%. Cost reductions by 10 to 20% by using innovative technologies for district heating and industrial customers should be reached. Other improvements up to 20 to 25% could also be targeted for energy demand of the pump, piping, and avoiding scaling and other undesired effects within the brine cycle. To achieve these goals, the main effort must be put on the development of new materials at lower cost (pipes, pump, additives, heat exchangers), the definition of new industrial process and treatment of the brine to limit scaling effects, reach higher efficiencies and develop cascade uses, the integration of the different system elements within an optimized overall system, the definition of measures to reduce possible environmental effects during normal or abnormal operation. These targets could be integrated in the DG Research work program concerning energy efficiency.

Towards a demonstration program integrating the different research areas

The achievement of the Soultz experiment and several successful spin off projects open the adult age for the development of EGS. The contribution of EGS sources must significantly increase during the coming years and technologies are already available to plan a demonstration program. The development of 20 EGS demonstration sites throughout Europe is considered as realistic and sufficient to show EGS feasibility. Already, some of the ENGINE partners are involved in ongoing or planned projects among which:

- Icelandic Deep Drilling Program (2008-2009) financed by a consortium of three leading Icelandic power companies, Hitaveita Sudurnesja Ltd., Landsvirkjun, Orkuveita Reykjavikur, together with Orkustofnun (National Energy Authority) and Alcoa Inc. (an international aluminium company).
- Zala County and Fabiansebestyen drill site (Hungary 2008-2009). Contacts have been established between MOL, the industrial supervisor, and the ENGINE steering committee to include these 2 projects within a demonstration program.
- Roquette project in the Rhine Graben. Contacts between the Soultz consortium and some other partners of ENGINE have concurred to design this project aimed at using steam from deep geothermal origin to dry the industrial production of starch.
- Kosice (Slovakia) in preparation by ENEL and others.
- Groß Schönebeck power plant (Germany), financed by German Government and an industry partner.
- Bruchsal power plant (Germany), financed by EnBW among others.
- Unterhaching co-generation plant (Germany), financed by local authority Unterhaching.
- Landau power plant (Germany), financed by a local power company.
- Podhale power plant (Poland) in preparation.
- Green Campus Izmir project (Turkey), in preparation with local institutions.

These projects will generate a learning curve for standardization of most operations. Their planning constitutes a roadmap for researchers, industry and funding agencies as a response to new perspectives of development of geothermal energy in order to contribute to the strategic objective of 20% renewable energy sources (RES) and CO2 reduction in the EU energy mix by 2020. An EGS foundation could be created based on the following up of these projects and could strengthen the links with industrial partners and result in a technological platform. This foundation should be aimed at keeping the present European knowledge for the management of non conventional (Soultz) and conventional reservoirs (France, Germany, Iceland, Italy) and transfer it for the development of zones of high potential (Greece, Pannonian basin of Hungary and Romania, Turkey) or out of Europe (Southern Australia, Western US, China, Indonesia, Japan, New-Zealand, Caucasia and Kamchatka in Federation of Russia).

Conclusion

The geothermal sector still needs generic technologies to expand the use of heat and power. This expansion must be performed in a strengthened international cooperation in order to stimulate global development, commercialisation, deployment and access to technologies. It must also design support schemes for co-generation and heating and cooling, combining other renewable energy sources and other low-carbon technologies. It will also promote education and training to deliver the quantity and quality of human resources that will be required, by making full use of the FP7 People Programme.