European Energy Research Alliance

Joint Program on Geothermal Energy

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and

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Brussels, 24th of March, 2010
Geothermal development scenarios in Europe

Electric energy generation:
• 3 - 6 GWe by 2020
• 15 – 30 GWe by 2050
--> mitigation of 0.3 Gigatonne CO₂/year

Heat and cooling generation
• 39 - 60 GWt by 2020
• up to 300 GWt by 2050
--> mitigation of 0.2 Gigatonne CO₂/year

1.5 GWe ONLY harnessed today, mainly Italy and Iceland
80 - 100 GWe geothermal resource potential stored up to 6 km depth for electric energy generation

Development scenarios for Europe

Sources: IEA and IPCC
Main challenges of JPGE

**Development of new cost-effective technologies**

- Improve the performance of existing geothermal systems
- Explore and exploit at large scale new untapped hydrothermal systems
- Deploy Engineered Geothermal Systems at large scale
- Access “high potential” geothermal resources such as supercritical fluids and magmatic systems

**Definition of innovative approaches and tools** suitable to:

- Improve risk assessment and management of the projects
- Secure the social acceptance of geothermal projects
- Provide guidelines to Regulatory Authorities and Policy Makers for sustainable development of geothermal energy
Overall goal
Development of new cost-effective technologies suitable for a sustainable growth of geothermal energy in Europe and worldwide

General structure of the JPGE

SP1 Resource Assessment

SP2 Accessing and engineering of the Reservoir

SP3 Process Engineering and Design of power systems

SP4 Operation and Management of Geothermal Systems

SP5 Sustainability, Environment and Regulatory Framework
EGIS European Geothermal Information System -

Innovative methodologies for geothermal exploration

Geothermal modeling and potential estimate

Natural Laboratories

Definition of the system architecture and format standards
Development of a universal data format and a data converter
Development and implementation of web services for data exchange and management

Implementation of EGIS and web services for data exchange and management

Development of innovative acquisition and imaging techniques for assessing reservoir structure and properties
Development of novel approaches for joint data acquisition and inversion of different geophysical methods into one reservoir model.

Best practice workflows and procedures will be developed for geothermal exploration in different geological environment.

Tools will be developed for resource assessment and high resolution 3D imaging of reservoir.

Testing and validation of new models and technologies developed for
• Low temperature hydrothermal systems
• EGS
• Supercritical fluid
• Magmatic systems

Models, technologies, and procedures will be validated for the different geothermal (Soultz, Basel, Iceland, Larderello, Gross Schönebeck),

Demonstration of applicability of innovative tools and validation of new models in different European sites (low temperature hydrothermal systems, EGS, supercritical, and magmatic systems)

Participants: BRGM, CEGL, CNR, CNRS, CRES, GFZ, ISES, ISOR LIAG, ETHZ, TNO (SP1 Coord.)

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SP1 - Resource Assessment

European Geothermal Information System

Well & Seismic Data

Log data

Logs
- Gamma ray (clay content)
- Sonic (density)
- Resistivity (various)

Petrophysics

Geological Atlas (TNO) 2004

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29-3-2010
SP1 - Resource Assessment

European Geothermal Information System

3D-Geological model

- Upper North Sea Group
- Lower and Middle North Sea Groups
- Chalk Group
- Rippland Group
- Schelde and Niederrhein Groups
- Allerod Group
- Lower and Upper Germanic Tries Groups
- Zechezien Group
- Lower and Upper Rotliegend Groups
- Limburg Group
- Carboniferous Limestone Group
- Devonian
- Silurian
- Ordovician

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• Innovative methodologies for geothermal exploration
regional-scale assessment of geothermal potential

integrating geophysical-geological modelling and joint interpretation of geophysical experiments to explore perspective drill locations

Muñoz, 2009

Moeck, 2008
Drilling and well completion technologies -
- Development of spallation drilling methods
- Optimization of drilling and completion technology of wells
- Large-scale laboratory demonstration of technology under supercritical conditions.

Engineering a Reservoir
- Geomechanic behaviour of fracture zones
- Development and evaluation of a single-well circulation system
- Induced microseismicity analysis
- Use of CO₂ for EGS
- Predictive model of the properties of fracture zones and faults
- Field test for a single-well circulation system in GeneSys Hannover project
- Numerical simulation using THOUGH REACT code for gas storage purposes.
- Hydraulic communication test at the well-doublet of Groß Schönebeck

Technologies for well logging
- Development of high-temperature down-hole tools including while drilling measurement
- Testing and calibration of
  - HT probe (up to 320°C),
  - Na-Li geothermometer,
  - tracer tests (up to 350°C)

Participants: BRGM, CNR, CNRS, CRES, ETHZ, GFZ (SP coordinator), ISOR, LIAG, TNO

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• Drilling and well completion technologies

Moeck, 2009
SP2 - Accessing and engineering a reservoir

Engineering a Reservoir
SP2 - Accessing and engineering a reservoir

Refined stimulation treatments to enhance hydraulic productivity while reducing the risk of seismic hazard

Location of induced seismic events

Kwiatek et al. 2009
Heat transfer process -
Development of heat exchanger modules.
Analysis of physical and chemical properties of fluids

Power systems
• Simulations of geothermal power loops for electricity generation
• A modular power loop (MoNiKa)
• Basic experiments on mixtures of working fluids,
• Holistic design approach for optimal efficiency of the whole geothermal power system

Installation of modular power loop for experimental/laboratory testing of components
Simulation of supercritical thermodynamic loop including design of heat exchanger and turbine
Erection of an Experimental power plant Groß Schönebeck

Storage and provision of heat and chill
Co-production of heat, chill and electricity simulation
Storage of heat and chill field test

Simulation of thermodynamic cycle with respect to the outcoupling of heat
Tests of heat/chill storage in various regions (Germany, France)

The improvements in heat transfer from geothermal fluid to the energy conversion system, the development of more efficient binary power systems will be demonstrated in different pilot projects.

Participants: BRGM, CNR, CNRS, CRES, GFZ, ISOR, KIT (SP coordinator)
SP3 Process Engineering of the Power System

Heat transfer process

- identification of new fluids and operational modes for a highly efficient closed fluid cycle
SP3 Process Engineering of the Power System

Power systems

setup of surface test facilities

MoNiKa
modular power loop for experimental/laboratory testing of components
Storage and provision of heat and chill

German Parliament Buildings, Berlin

Kältespeicher

Wärmespeicher

h: Nutzen/Aufwand

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JPGE SP4 - Operation and management of geothermal systems

**Research Area**

- Improvement of sustainability of geothermal resources
  - Reservoir management by sophisticated reservoir models
  - Monitoring of reservoir response to production
  - Models and tools to predict reservoir performance
  - Best practice handbook for monitoring and management
- Chemical and biological processes in reservoirs and surface installations
  - Chemical and biological by-products
  - Chemical processes in reservoirs and boreholes
  - Chemical processes near the critical point
  - Improved production methods, including new design concepts, better production schemes and use of chemical inhibitors
- Prolonged lifetime of boreholes and system components
  - Corrosion and scaling
  - Material selection
  - Improvement of maintenance procedures
  - New design concept and procedures for optimization of operation and maintenance of system components

**Outcomes**

- Reliable reservoir models, intelligent design of surface installations, careful selection of system components, operation procedures will be validated in different geothermal systems in Europe

**Participants:** BRGM, CEGL, CNR, GFZ, ETHZ, ISOR (SP coordinator), LIAG

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SP4 - Operation and management of geothermal systems

Improvement of sustainability

- simulator for thermally, hydraulically, mechanically, and chemically coupled processes for geothermal reservoirs
Prolonged lifetime of boreholes and system components

- quantification of corrosion and scaling processes in geothermal systems during operation.
JPGE SP5 - Sustainability, Environment and regulatory framework

**Total Life Cycle Analysis - LCA -**
- Life Cycle Inventory Analysis
- Life Cycle Impact Assessment
- Life Cycle Costing methodologies
- EXTERNE methodology application

**Social multi-criteria evaluation**
- Generation of the alternatives options
- Identification of the evaluation criteria
- Application of a multi-criteria aggregation procedure
- Conflict analysis

**Risk assessment, mitigation and management**
- Methodology for risk assessment
- Real option models
- Seismic hazard assessment and mitigation

**Economic evaluation**
- Methodology for the economic evaluation
- Non-reductionist approaches

**Regulatory framework**
- Regulatory Impact Analysis (RIA).
- Compliance strategies and monitoring mechanisms

**OUTCOME**
- Parameter of plants in different alternative areas and with different technological components
- New approaches and tools for performance evaluation and social acceptability by local stakeholders, will be applied and validated for the development of pilot projects in different European countries
- Guidelines and tools will be developed to fulfill the expectations of geothermal investors and decision makers
- Procedures for reliable economic assessment and sustainability assessment
- Guidelines for regulatory bodies for the licensing of geothermal site development

**Participants:** BRGM, CEGL (SP coordinator), ETHZ, GFZ, ÍSOR, TNO

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Partnership and resources

A total of 253 person years/year, for an equivalent budget of about € 25 MILLION/year, will be working with different roles and responsibilities for the JPGE’s foreseen research activities and research infrastructure such as laboratories and computer facilities will be used and exchanged among the 12 Participants.

<table>
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<th>Participants Name</th>
<th>Short Name</th>
<th>Country</th>
<th>Human Resource committed (persons/year)</th>
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<td>Bureau des Recherches géologiques et minières</td>
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<td>Centre of Excellence for Geothermal Energy-Larderello</td>
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Education and dissemination

European geothermal PhD day

Friday 12th of February 2010 in Potsdam, Germany

Master in:
"Geothermal project development"

October 2010  - CEGL, Larderello - Italy
Conclusions

R&D
- solving the key issues where basic research is required
- create international science teams and science partnership with industry (capacity building)

Politics
- framework conditions for renewables
- invest in R&D (e.g. drilling program)

Economy
- value added from geothermal
- driving force for technology

Learning curve for distributed economical provision of geothermal energy

EERA JPGE - THE GEOTHERMAL R&D PROGRAMME FOR EUROPE

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Thank you for your attention

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