Post ENGINE tasks – What remains to be done?

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ENGINE status

The EU project ENGINE was a major step forward to move EGS ahead. It assembled a large, knowledgeable group of wide specialization; the results will represent a milestone in EGS R&D.

Yet it must be realized that only an intermediate position has been established on a still long way to reach the ultimate EGS goal:
development of a technology to produce electricity and/or heat from a basically ubiquitous resource, in a manner relatively independent of site conditions.

There are still major knowledge gaps, unanswered questions, and unavailable solutions to work on.
Here only a selection will be addressed.

EGS requirements

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Although the minimum requirements for an economically viable EGS reservoir are set since quite some time about

- **total volume**
- **total heat exchange surface**
- **flow impedance**
- **thermal and**
- **stress-field properties,**

their realization in a tailor-made manner to comply with differing site conditions is not yet demonstrated.

Target parameters

Garnish, 2002

- Water flow rate . . . . 50-100 kg/s
- Effective HX area . . . .> 2 x 10^6 m^2
- Rock volume . . . .> 2 x 10^8 m^3
- Impedance . . . . 0.1 MPa/(kg/s)
- Water loss . . . . < 10%

„BEST PRACTICES“

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The creation, characterization and operation of an EGS reservoir at depth needs techniques of remote sensing and remote control; here we are still far from having “best practices”.

First attempts seem to function

- **HEX-B to evaluate in-situ conditions form wellhead data**
- **HEX-S to plan and evaluate hydraulic stimulation**

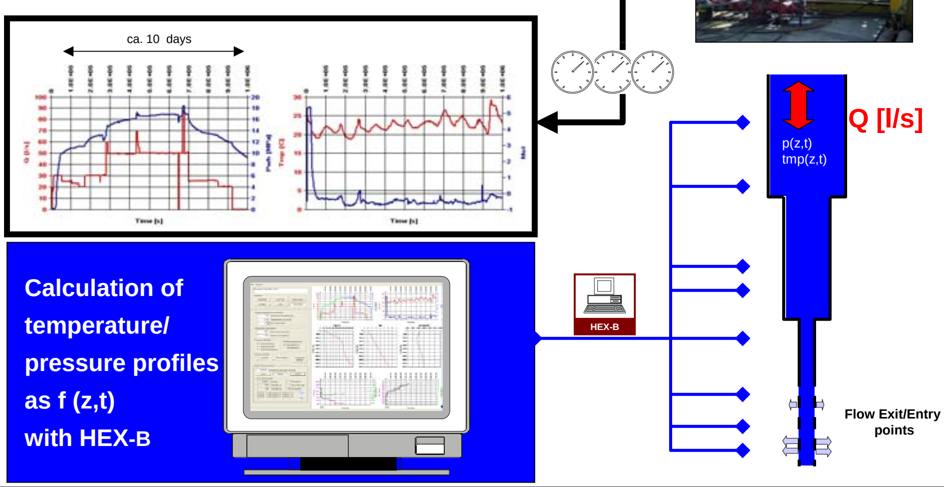
➢**Definitely more tools and data processing & interpretation are needed to come up with best solutions.**

Software “HEX-B”, © by GEOWATT AG

pT – wellbore simulator

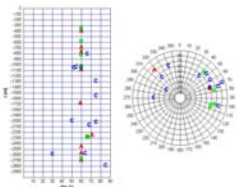
European EGS Project Soultz-sous-Forêts, France:
Stimulation GPK3, 2003

Wellheads GPK2/GPK3



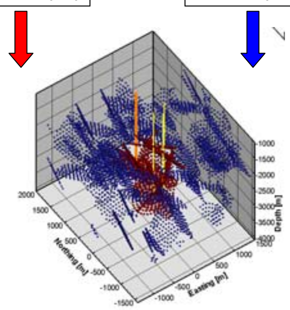
Software “HEX-S”, © by GEOWATT AG

Stimulations-Code HEX-S



Deterministic structures (UBI)

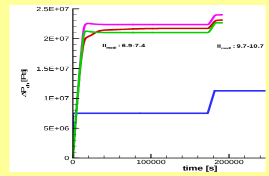
Stochastic structures (Σ UBI)

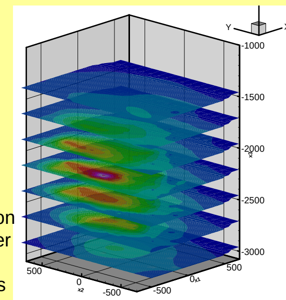


EGS Project Coso, USA

Coupled hydro-mechanic code

Wellhead pressure





Pressure distribution in the reservoir after After injection for 24 hours with 45 l/s

Engineering an EGS reservoir

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Many questions of rock mechanics like the degree of anisotropy, stress propagation/ transmission – fast, „dry“? slow, „wet“?
(under different site conditions)
are unanswered;

Connectivity throughout a planned reservoir cannot yet be engineered.

Induced seimicity

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How to control stimulation-induced seismicity?

Most economic and long-term production models assume uniform reservoir permeability and heat exchange surfaces, consisting of numerous, well-distributed fractures.

If stimulation results in larger seismic events the created, correspondingly extended single fractures could easily form short-circuiting pathways.

Magnitude ←→ fracture extent

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The magnitude depends on several parameters, among others:

- **dislocation / slip on the rupture surface**
- **size of the rupture**

The relationships are complex, yet some rough estimates can be given:

Magnitude	Shear slip	Radius of fracture surface
0	< 0.5 mm	< 10 m
2	< 5 mm	< 100 m
4	< 5 cm	< 1 km
6	< 0.5 m	< 10 km

Source: Swiss Seismological Survey

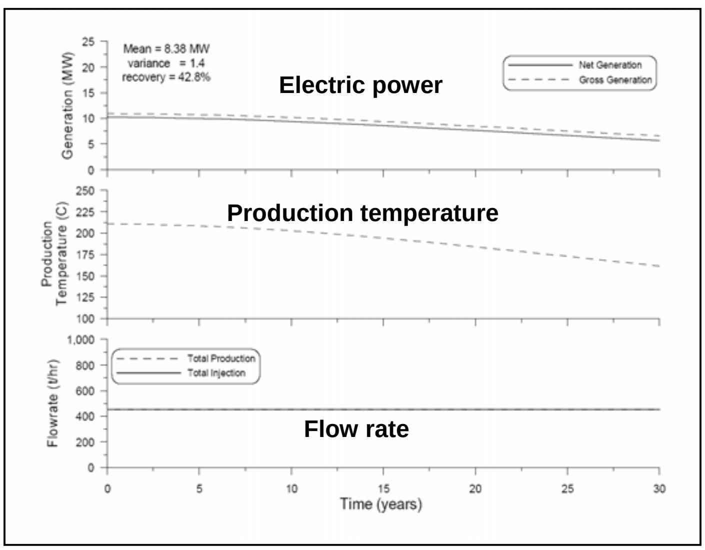
Long-term behaviour

There is no experience about possible changes of an EGS heat exchanger with time.

Permeability enhancement (e.g. new fractures generated by cooling cracks) could increase the recovery factor,

while permeability reduction (e.g. by mineral reactions) or short-circuiting could reduce recovery.

Numerical model simulations (Sanyal & Butler 2005)



Assumption: no change in the reservoir over 30 years

How to upscale EGS power production?

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So far the envisaged electric power capacity of EGS systems is limited at a few MWe.

But in order to play a significant role in electricity supply a system capacity of at least several tens of MW_e would be essential.

One of the main future R&D goals will be to see whether and how the EGS power plant size could be upscaled, Possibly by some unconventional measures – still to be developed.

The future of EGS ?

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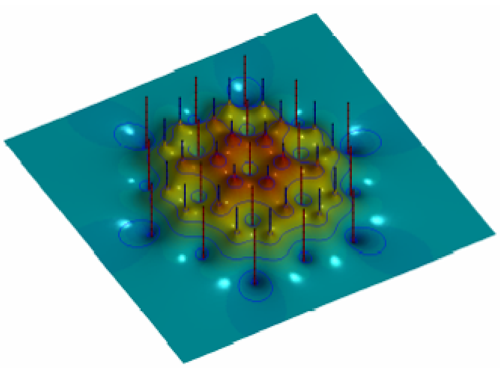
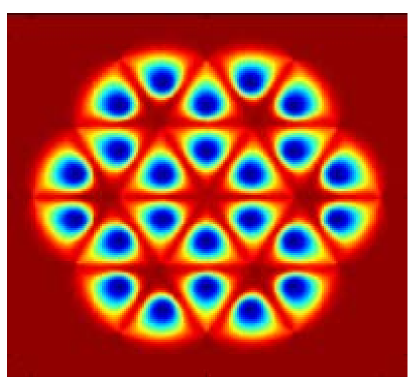
Computer modelling of large scale HFR development in the Cooper Basin after 20 years of production (19 injection wells and 24 production wells)

(Source: GEODYNAMICS Ltd., Australia)





Total capacity with 43 boreholes: up to 200 MWe

Risks and financing

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Environmental and social risks have been addressed at

- ENGINE Workshop 6 **"Increasing policy makers awareness and the public acceptance"** Athens/GR, 13-14 September 2007 , and
- ENGINE Workshop 7 **"Risk analysis for development of geothermal energy"** – Leiden/NL, 7-9 November 2007

For prospective investors a well-designed cost / risk analysis and corresponding measures still remain to be developed.

OUTLOOK

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- The competence and working spirit of the ENGINE team should by all means remain focussed and united.
- Already existing, important but not yet realized R&D action plans like GEISER should be rapidly implemented.
- And most importantly: as many kilowatt-hours of electricity as possible needs to be produced from EGS sources, as soon as possible.