Overview of the Soultz geothermal project

Pierre Durst, based on GEIE GMC presentation

BRGM

Pisa, 08/10/2013
The Soultz geothermal concept

**Hot Dry Rock**
- Acronym HDR
- Heat exploitation from deep hard rocks
- High temperatures at great depth
- Not dependent from the location
- Create artificially a heat exchanger at depth
- Closed system

**EGS**
- Enhanced Geothermal System
- Natural brine 100g/l, NaCl, pH~5
- Naturally Fractured and Altered Granite
- Connection between geothermal well to the reservoir by stimulation
- Forced fluid circulation during exploitation

> Large reservoir with similar fluid composition: open system
Groupement Européen d’Intérêt Économique
“Exploitation Minière de la Chaleur” GEIE EMC

Industrial Partners

Public Funding

Scientific Partners

Supported by INTELLIGENT ENERGY EUROPE
HDR concept to EGS concept

HDR : Hot Dry Rock

Artificial creation of a reservoir in hard rock by hydraulic fracturing

EGS : Enhanced Geothermal System

- In non-volcanic area
- In non-conventional reservoirs (low permeability fractured granite)
- Fluid presence

Neither Hot nor Dry, not even Rock!

EGS: natural fractured geothermal reservoirs + hydraulic or chemical stimulation to enhance hydraulic properties
Geological setting

- Rhenan fault
- Kutzenhausen fault
- Soultz fault
- Tertiary sediments
- Jurassic-Triassic sed.
- Granitic basement

Maps showing geological formations and fault systems.
Thermal setting

Temperature at 5000m

Temperature at 1500m

Soultz-sous-Forêts

- Trias
- Granite
- Tertiary
From Péchelbronn oil to EGS
The main project steps

1987 – 1991
Exploration phase
- Drilling GPK1 at - 2000 m
- Coring EPS1 at - 2227 m

Creation of the 2 wells system GPK1/GPK2 at - 3600 m
- Deepening of GPK1 at - 3600 m and stimulation
- Drilling of GPK2 at - 3880 m and stimulation
- Circulation test between the 2 wells (4 months)

1999 – 2007
Creation of the 3 wells system GPK2/GPK3/GPK4 at - 5000 m
- Deepening of GPK2 at - 5080 m and stimulation
- Drilling of GPK3 at - 5100 m and stimulation
- Drilling of GPK4 at - 5270 m and stimulation
- Circulation test between the 3 wells (5 months)
- Complementary stimulations (chemical)

2007 – 2009
Construction of the first production unit ORC - 1.5 MWe
- Installation of surface equipment (turbine and generator, heat exchangers, cooling systems ...)
- Installation of the LSP in GPK2 at - 350 m
- Inauguration of the power plant 13.06.2008
- Installation of the ESP in GPK4 at - 500 m

2010-2012
1984-1987: Beginning of the Franco-German project

The preliminary work was carried out by

* BRGM
* Geologisches Landesamt of Baden-Württemberg

The Franco-German cooperation agreement was signed in 1987.

The Soultz-sous-Forêts site was selected because it has been renowned for its thermal waters, for centuries, and was drilled and closely studied, during the oil exploitation.
1987-1991: drilling of the first wells

Drilling of two wells

- GPK1 was drilled down to a depth of 2000 metres as an exploration well
- EPS1 was drilled down to a depth of 2227 metres for drill-core sampling
THE MAIN PROJECT STEPS

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2010-2012

GEOELEC

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1997 Circulation test

Upper reservoir: 2800-3600 m
Test duration: 4 months
Production temperature: 140°C
Thermal output: 10 MWth
No fluid losses
THE MAIN PROJECT STEPS

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Since 1987:
- EPS1 fully cored ➔ exploration well
- GPK1 ➔ Injection well
- GPK3 ➔ Injection well
- GPK2 & GPK4 ➔ Production wells

Soultz site

BHT=200°C
THERMAL PROFILES IN THE SOULTZ WELLS

Conduction

Triassic sandstone

Paleozoic granite

Convection

Natural circulation within hydrothermally altered and fractured zones

Fractured Altered Granite

Fractured Sandstone
GEOCHEMICAL CHARACTERISTICS OF THE BRINE

- Representative chemical composition: Na-Cl brine, pH ≈ 4.8-5.0
- TDS ≈ 97 g/l and density = 1.065 g/cm³ (20°C)

Sanjuan et al., 2008
FRACTURE ≠ PERMEABILITY

Drilled ~ 14 km in granite

Observed several thousand of fractures

Only some of them are permeable at borehole scale

Important fracture filling by secondary minerals

Gentier et al., 2010
Hydraulic stimulation

1993-1996: stimulation du réservoir à 3600 m de profondeur / Stimulation des Reservoirs in 3600 m Tiefe (GPK1 & GPK2)
- débit max. / Max. Fließrate : 50 l/s
- pression max. / Max. Druck: 13 MPa

2000: stimulation de GPK2 / Stimulation in GPK2 (5 km)
- débit max. / Max. Fließrate : 90 l/s
- pression max. / Max. Druck: 18 MPa

2003: stimulation de GPK3 / Stimulation in GPK3 (5 km)
- débit max. / Max. Fließrate : 45 l/s
- pression max. / Max. Druck: 17 MPa

2004: 1ère stimulation de GPK4 / 1. Stimulation in GPK4 (5 km)
- débit max. / Max. Fließrate : 45 l/s
- pression max. / Max. Druck: 19 MPa

2005: 2ème stimulation de GPK4 / 2. Stimulation in GPK4 (5 km)
- débit max. / Max. Fließrate : 45 l/s
- pression max. / Max. Druck: 19 MPa

Cuenot et al., 2008
MICROSEISMIC CLOUDS

- Several thousands of microseismic events during each stimulation test

- Several felt earthquakes (M > 2)

- Maximum magnitudes
  - 2000 : 2.6
  - 2003 : 2.9, 2.7
  - 2004 : 2.0
  - 2005 : 2.6
Chemical stimulation

Avant 2005 / Vor 2005: Stimulation avec de l’acide chlorhydrique / Stimulation mit Salzsäure (GPK2, GPK3 & GPK4)

2006-2007: Programme de stimulations chimiques / Abfolge der chemischen Stimulationen
- RMA (Regular Mud Acid), GPK4
  → argiles, feldspaths, micas / Ton, Feldspat, Glimmer
- Chelatants, GPK4
  → calcite / Kalk
- OCA (Organic Clay Acid), GPK3 & GPK4
  → argiles / Ton

<table>
<thead>
<tr>
<th>Puits</th>
<th>productivité initiale</th>
<th>après stimulation hydraulique</th>
<th>après stimulation chimique</th>
</tr>
</thead>
<tbody>
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<td>ursprüngliche Produktivität</td>
<td>nach hydraulischer Stimulation</td>
<td>nach chemischer Stimulation</td>
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<td>GPK2</td>
<td>0.01 - 0.03 l/s/bar</td>
<td>0.8 l/s/bar</td>
<td>-</td>
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<tr>
<td>GPK3</td>
<td>0.2 l/s/bar</td>
<td>0.35 l/s/bar</td>
<td>0.39 l/s/bar</td>
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<tr>
<td>GPK4</td>
<td>0.01 l/s/bar</td>
<td>0.2 l/s/bar</td>
<td>0.5 l/s/bar</td>
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Nami et al. (2007), Tischner et al. (2007)
Circulation tests

- 2005 (5 months): 32 events, magnitude ≥ 1.3
  - 4 events, magnitude > 2,
  - Maximum magnitude: 2.3

- 2008: 4 events, magnitude ≥ 1.3
  - Maximum magnitude: 1.4

- 2010 (323 days): 19 events, magnitude ≥ 1.3
  - 4 events, magnitude > 2
  - Magnitude maximum: 2.3

- 2011 (3.5 months): 2 events, magnitude ≥ 1.3
  - Magnitude maximum: 1.7

- 2011 (2.5 months): no event, magnitude ≥ 1.3

Cuenot et al., 2008
Dorbath et al., 2009
Genter et al., 2010
Tracer tests and hydraulic modelling

GPK-2 Well

GPK-4 Well

Strong hydraulic dissymetry between GPK3/GPK2 & GPK3/GPK4

70% of external water: open system

Sanjuan et al., 2006
# The Main Project Steps

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<thead>
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<tbody>
<tr>
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**GEOELEC**

Supported by [Intelligent Energy Europe](http://www.intelligent-energy.eu)
Soultz Power plant (Organic Rankine Cycle)

Heat exchangers

Condenser

Well heads
Soultz Power plant (Organic Rankine Cycle)

Simplified sketch of the Soultz ORC power plant.
Current exploitation state

2011 Electric power production
- 19 l/s (70m³/h)
- 18.5 bar
- 160°C
Reservoir monitoring

- Flowrate
- Temperature
- Pressure
- Induced micro-seismicity
- Fluid physico-chemistry
- Tracer tests
Power plant technology
Corrosion

- High (production) and low (reinjection) temperature experiments
- Different steels tested
- Coating experiments
Power plant technology
Scaling

- Main minerals: Barite-Celestine (Ba, Sr) SO₄ & Galena (PbS) and trace minerals (other sulfides)

Scaling: mineral deposits

- Investigations about anti-scalants with a German company
- Comparison of the effectiveness of several polyphosphonates
- Laboratory experiments with closed bottle tests
- Artificial solutions and original fluid (GPK2)

SEM - Microscopy
Barite-Celestine dominated. Only traces of sulfides
Power plant technology
Down-hole pumps

- ESP: Electrical failure in 2009
- LSP: Failure in 2011
Environment

- Natural radioactivity due to scaling in the surface installations
  - Regular monitoring
  - Workers protection (blue line, dosimeters)
  - Waste management

- Noise study for population acceptance

- Seismic nuisance
  - Monitoring
  - Lowering of the reinjection overpressure

- Public polls, public communication
Dissemination

The main purpose of the Géothermie Soultz site is to be:

- an operational pilot system and power plant
- available for studies and research

The observation of its running is essential to:

- better understand the subterranean phenomena
- optimise the new deep geothermal plants (Insheim, Landau)

The site is a gathering place for researchers, engineers and students, who can be inspired by the experimentation and can then contribute to better geothermal management

More than:

- 230 peer-reviewed papers
- 700 presentation in conferences
- 120 diploma student (40 PhD)
Dissemination

- optimise the new deep geothermal plants (Insheim, Landau)

Produced fluid temperature: 140°C
Good permeability

Produced fluid temperature: 160°C
Lower permeability
Permeability enhancement more problematic
For further informations

English – German - French website

http://www.geothermie-soultz.fr/
Thank You!
VISIT GEOELEC.EU