Geothermal Energy: New Challenges and opportunities

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Geothermal Energy is Renewable

From the RES directive of the EU, 2009/28/EG:

Energy from renewable sources’ means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases;

‘Geothermal energy’ means energy stored in the form of heat beneath the surface of solid earth;

‘hydrothermal energy’ means energy stored in the form of heat in surface water;
Worldwide technical potential of renewable energy sources (EJ per year)

- Hydropower: 50 EJ per year
- Biomass: 276 EJ per year
- Solar energy: 1575 EJ per year
- Wind energy: 640 EJ per year
- Geothermal energy: 5000 EJ per year

World Energy Assessment 2000
The heat stored in the Earth’s crust

The geothermal energy resource is huge but we have technical problems to harness it.
Classification of geothermal energy

Three main types of geothermal fields for electricity production:

- High temperature fields (T > 200°C at 1 km depth)
- Medium temperature fields (100 < T < 200°C at 1 km depth)
- Low temperature fields (T < 100°C at 1 km depth)

We distinguish between:

- Conventional geothermal systems
- Unconventional geothermal systems
Conventional geothermal system

- Power Plant
- Market
- Borhole
- COLD ROCK
- HOT ROCK
- Permeable fractures
- Fluid recharge
Almost all geothermal power plants in the world today are conventional.

Olkaria, Kenya

Photo: Ingvar Birgir Friðleifsson
Unconventional geothermal fields are of three main types:

- Hot Dry Rock Systems (HDR)
- Enhanced Geothermal Systems (EGS)
- Supercritical Geothermal Systems (SGS)
Hot Dry Rock Systems (HDR)

Injection well

Production well

Power Plant

Market

COLD ROCK

Unfractured none-permeable rock

Artificially created permeability

HOT ROCK

Hot Dry Rock Systems (HDR)
Enhanced geothermal system (EGS)

Artificially enhanced permeability

HOT ROCK

COLD ROCK

Injection well

Production well

Power Plant

Market
Supercritical geothermal systems

- Are supposed to exist in the roots of the high temperature geothermal fields near the magmatic heat source.
- Should give energy intensive fluids.
- Might be chemically difficult to handle.
- Both very high temperature and permeability are necessary to get supercritical fluids.

Powerful well with corrosive fluid in Krafla in 2007

Photo: Elvar J. Eiriksson, ÍSOR
Geothermal Energy is either used directly or to produce electricity.

Direct use includes space heating, green houses, bathing and swimming, drying, fish farming, etc.

High temperature geothermal energy is used to produce electricity.
## Renewable energy – Electricity 2005

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Production TWh</strong></td>
</tr>
<tr>
<td>Hydro</td>
</tr>
<tr>
<td>Biomass</td>
</tr>
<tr>
<td>Wind</td>
</tr>
<tr>
<td>Geothermal</td>
</tr>
<tr>
<td>Solar</td>
</tr>
<tr>
<td>Tidal</td>
</tr>
</tbody>
</table>
Installed Geothermal power in 2007

TOTAL INSTALLED CAPACITY IN 2007 = 9.7 GW
Installed geothermal power 1995, 2000 and expectation for 2010
Installed geothermal power in 1975-2010
Average levelized cost of electricity from different renewables (ESMAP 2007)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rated output</th>
<th>Average levelized cost$^{1}$, current and predicted, in US¢/kWh</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Biomass Gasifier</td>
<td>20 MW</td>
<td>7.0</td>
</tr>
<tr>
<td>Biomass Steam</td>
<td>50 MW</td>
<td>6.0</td>
</tr>
<tr>
<td>Geothermal (binary)</td>
<td>20 MW</td>
<td>6.7</td>
</tr>
<tr>
<td>Geothermal (flash)</td>
<td>50 MW</td>
<td>4.3</td>
</tr>
<tr>
<td>Hydro</td>
<td>100 MW</td>
<td>5.4</td>
</tr>
<tr>
<td>Pumped Storage Hydro</td>
<td>150 MW</td>
<td>34.7</td>
</tr>
<tr>
<td>Solar-thermal (without thermal storage)</td>
<td>30 MW</td>
<td>17.4</td>
</tr>
<tr>
<td>Solar-thermal (with thermal storage)</td>
<td>30 MW</td>
<td>12.9</td>
</tr>
<tr>
<td>Wind</td>
<td>100 MW</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Total cost per energy unit

- Binary system
- Flashed condensing plant
- Combined condensing and binary system (bottoming cycle)

Well output (MW$_e$/well) vs. Total cost per energy unit (EURcents/kWh)
Expected future trend for geothermal electricity:

- Conventional systems
  - South and Central America (Chile, Argentina, Equador, Nigaraqua)
  - USA
  - East Africa (Kenya, Ethiopia, Djibouti, Eritrea)
  - Asia: (Indonesia, Philippines, Iran, India)
  - Europe: Iceland, Turkey, Portugal (Azores), Russia, Italy, Greece

- Enhanced Geothermal Systems (EGS)
  - Ongoing experiments in several countries like Australia and Germany and USA is taking off again. If successful, enormous power supply will open up worldwide. Iceland has huge resources that might be harnessed by EGS technology
Australia – Extensive EGS projects on-going

- Huge areas with temperature of 200-300°C at ~5 km depth
- In the top of a huge granite complexes insulated by sediments above.
- Horizontal fractures expected at 4-5km depth.
- Expected production in closed loops.

- Australian Governments committed A$100+ million for research & demonstration since 2000 to 2007
President Obama Announces Over $467 Million in Recovery Act Funding for Geothermal and Solar Energy Projects

- Geothermal Demonstration Projects ($140 Million)
- Enhanced Geothermal Systems Technology Research and Development ($80 Million)
- Innovative Exploration Techniques ($100 Million)
- National Geothermal Data System, Resource Assessment, and Classification System ($30 Million)
Chile: Huge remote resources

- 300 probable geothermal fields
- Estimated potential of
- 3500 MWe from conventional geothermal resources
Iceland – huge resources for conventional and for EGS-technology:
Iceland – Geothermal volumetric assessment:

<table>
<thead>
<tr>
<th>Area</th>
<th>Area km²</th>
<th>Harnessable electrical energy</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Above 130°C. EJₑ</td>
<td>Above 130°C. TWhₑ</td>
</tr>
<tr>
<td>The volcanic zone</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Known geothermal fields</td>
<td>600</td>
<td>5.6</td>
<td>1,556</td>
</tr>
<tr>
<td>Other active areas</td>
<td>2,150</td>
<td>13.2</td>
<td>3,667</td>
</tr>
<tr>
<td>Non-active areas</td>
<td>29,250</td>
<td>38.1</td>
<td>10,583</td>
</tr>
<tr>
<td>Total inside the volcanic zone</td>
<td>32,000</td>
<td>56.9</td>
<td>15,806</td>
</tr>
</tbody>
</table>

From Pálmason et al. 1985
Conclusions

- There is considerable potential world wide for increased production of geothermal power at reasonable prices.
- There is a huge potential for power production world wide from geothermal resources using EGS technology.
- The main challenges in the geothermal sector to day is:
  - Develop EGG technology for medium and high temperature fields.
  - Develop methods for extracting energy from supercritical fluids.
  - Improve technology for conventional geothermal production.
  - Make governments, international organizations and decision makers aware of the geothermal potential and help them to understand how to explore and exploit geothermal energy.
What can GEORG do?

- Facilitate co-operation between Icelandic geothermal players and strengthen their collaboration with recognized geothermal institutions in Germany, France, USA and New Zealand.
- Promote and increase general awareness of geothermal energy utilization and explain the principles and potential of this renewable and benign source of energy.
Thank you for your attention