Geothermal Exploitation–Relevance of Sedimentary Basins as Geothermal Resource

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Utilize geothermal energy to prevent quakes: Expert
Times of India – Delhi- 15th March 2011

"Geothermal energy travels from its source situated at the centre of the earth towards the surface where it leads to geodynamism and geothermal events like volcanic eruptions, high heat flows and earthquakes. If this energy is tapped, used for generating electricity, not only will events like earthquakes cease but the earth's temperature can also be brought down"
Presentation Outline

• Background
• Sedimentary Basins as Geothermal resource
  – Exploration and exploitation
  – Challenges and opportunities
• Indian potential and perspectives
Objectives and Important concepts

• Objective of geothermal power:
  – Produce a pressurized, high enthalpy vapour that can drive a turbine
    • Steam / low boiling point fluid

• Important concepts
  – Thermodynamic Properties of water / motive fluid
  – Pressure Vs Geothermal gradients
  – Behaviour of fluid in reservoir/ well
  – Manipulation of pressure / temp
Types of Geothermal resources
Hydrothermal Systems

3 pre-requisites:
• Fluid
• Heat /high temperature source
• Reservoir Permeability.
• Volcanic Hydrothermals:
  – High temperatures and steep Geothermal gradients at shallow depth
  – Steam as fluid- Direct use in steam turbine-high eff.
  – Low mass flow rates suffice
Most attractive commercially and popular.
Geothermal Regions (Volcanic)

Source: web
Volcanic Hydrothermal Power - World

Geothermal Power Plants

Source: web
Geothermal Power - World

Source: web
Hot-Rock Enhanced Geothermal System

1. Holes are drilled deep in hot, hard rock such as granites
2. Standard hydro-fracturing technology creates network of cracks in the hot rocks
3. Water flows down the injection wells, returns up the production wells, and is re-circulated
4. Heat is extracted from the produced water into a closed loop of working fluid
5. Electrical power is generated using conventional turbines

Source: web
Hot Rock Systems

- Enhanced Geothermal Systems (EGS)
  - Heat is available
  - Permeability and fluid are constraints
    - Created artificially by fracturing and injection

- Major risk factors
  - Fracturing to achieve hydraulic connectivity between producer & injector in target hot rock
  - Economics of drilling and fracturing of wells
Sedimentary Hydrothermal Systems - Exploration & Development Challenges

• With increasing depth
  – Rock hardness increases
  – Porosity & permeability decreases
  – Higher pressure gradient but lower Temp gradient
    • Diminishing possibility of reservoir steam
  – Drilling technological challenges
  – Capital Intensive

• Exploratory uncertainty:
  – Achieving permeability and establishing connectivity between injector & producer wells

• Produced fluid characteristics and volume
  – Determines conversion efficiency and size
Sedimentary Hydrothermal Systems

• Development Requirements
  – Identification of highly porous and permeable hot (Temp>100ºC) sedimentary rock
  – High fluid flow rates of production and injection
    • Order of magnitude higher than oil wells’ prodn.
  – Use of Organic Rankine Cycle to convert low temperature heat to power
    • Low efficiency of conversion, but high capital cost.
Sedimentary Hydrothermal Systems - Oil and Gas bearing Sedimentary Basins

- Intensively explored for oil and gas
- Well known temperature gradients
- Rocks/Sands have sufficient thickness, porosity and permeability
- Large fluid flow rates at moderate temperatures
- Depths that are not so great that drilling costs make the potential system uneconomic
- Co-production of geothermal energy with oil production
- Utilization of appropriate depleted oil/gas fields/wells for geothermal exploitation
Sedimentary Hydrothermal Systems -
Case Studies
Operational Plants
<table>
<thead>
<tr>
<th>Location:</th>
<th>Unterhaching, Bavaria (Germany)</th>
<th>Neustadt-Glewe (Germany)</th>
<th>Landau (Germany)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production:</td>
<td>CHP</td>
<td>CHP</td>
<td>CHP</td>
</tr>
<tr>
<td>Geology:</td>
<td>Southern German Molassis Basin (malmkarst)</td>
<td>Northern German Basin (depth between 1,5 and 2 km)</td>
<td>UpperRhine Valley (Graben) - exploration facilitated through oil drillings</td>
</tr>
<tr>
<td>Number of drilled wells:</td>
<td>2 wells</td>
<td>2 wells (development well in 1988 and the reinjection well in 1989 )</td>
<td>2 wells</td>
</tr>
<tr>
<td>Depth of drillings (m):</td>
<td>3,350m (development well) and 3,580m (reinjection well)</td>
<td>2,250m (development well) and 2,335m (reinjection well)</td>
<td>3000m (production well) and 3100m (reinjection well)</td>
</tr>
<tr>
<td>About the resource:</td>
<td>122°C and 150 l/s for the production well with stimulation</td>
<td>Maximum 98°C and flow rate between 40 and 110 m³/h</td>
<td>155 °C and flow rate between 50 to 70 l/s</td>
</tr>
<tr>
<td>Heat production:</td>
<td>35 MWth and up to 150 l/s from the production well with stimulation</td>
<td>6,5 MWth from geothermal and about 16,000 MWh</td>
<td>5MWth (supplies 300 households)</td>
</tr>
<tr>
<td>Uses of heat:</td>
<td>District heating: supplying 3,500 households</td>
<td>District heating: 1,325 residential units and 23 small commercial customers</td>
<td>District heating</td>
</tr>
<tr>
<td>Production of electricity:</td>
<td>3,36 MWe and 21,500 MWh</td>
<td>230 kWe (maximum 1,600 MWh and supplies up to 500 households)</td>
<td>3.8 MWe (supplies 6,000 households)</td>
</tr>
<tr>
<td>Technology used</td>
<td>Kalina technology</td>
<td>ORC</td>
<td>ORC</td>
</tr>
<tr>
<td>First year of production:</td>
<td>2007 (start in October) for heat production and 2009 (start in June) for electricity production</td>
<td>1995 for heat production and 2003 for electricity production</td>
<td>January 2008</td>
</tr>
<tr>
<td>Environmental impact:</td>
<td>Annual CO2 savings of 35,000 tons</td>
<td>Annual CO2 savings of 5,600 tons</td>
<td>Annual CO2 savings of 6,000 tons.</td>
</tr>
<tr>
<td>Global amount of investment:</td>
<td>80 M€</td>
<td>9,5 M€</td>
<td>21 M€</td>
</tr>
</tbody>
</table>

Source: GEOFAR
<table>
<thead>
<tr>
<th><strong>Location:</strong></th>
<th>Beowawe, Nevada (United States)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Program Area:</strong></td>
<td>Hydrothermal Low-Temperature and Coproduction</td>
</tr>
<tr>
<td><strong>About the resource:</strong></td>
<td>3900 gpm- low-temperature (205°F) brine. Brine is re-injected to the geothermal reservoir</td>
</tr>
<tr>
<td><strong>Production of electricity:</strong></td>
<td>1.5 MW of electricity</td>
</tr>
<tr>
<td><strong>Technology used for the electricity production</strong></td>
<td>ORC</td>
</tr>
<tr>
<td><strong>Start date:</strong></td>
<td>December 11, 2009</td>
</tr>
<tr>
<td><strong>Project Completion date</strong></td>
<td>December 31, 2012</td>
</tr>
<tr>
<td><strong>Amount of investment:</strong></td>
<td>$4,394,380</td>
</tr>
<tr>
<td><strong>Current Status:</strong></td>
<td>Producing 1.8MW of electricity</td>
</tr>
<tr>
<td><strong>Impacts:</strong></td>
<td>The binary plant is an Innovative application new to low-temperature geothermal energy production, adding 10% additional power to the existing plant. The produced power has good economics in high price region as well.</td>
</tr>
</tbody>
</table>

Source: GEOFAR
Sedimentary Hydrothermal Systems

Case Studies

Projects under development
<table>
<thead>
<tr>
<th>Location</th>
<th>Production</th>
<th>Geology</th>
<th>Number of drilled wells/number of planned wells</th>
<th>Depth of drillings (m)</th>
<th>Results about the resource</th>
<th>Heat production</th>
<th>Uses of heat</th>
<th>Production of electricity</th>
<th>First studies lead on the project and/or the area</th>
<th>Objective of production year</th>
<th>Environmental impact</th>
<th>Global amount of investment</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirchstockach (Bavaria), Germany</td>
<td>Electricity production</td>
<td>Southern German Molasse Basin</td>
<td>First drilling successful/Creation of a doublet</td>
<td>More than 4250 meters</td>
<td>138,4 °C and more than 100 l/s</td>
<td>45 MWth</td>
<td>Drying processes of aggregates for the production of dry cement for the production hall of Ganser Gruppe and district heating (under evaluation)</td>
<td>5,5 MWe (instead of 4 MWe for the first estimation)</td>
<td>2004</td>
<td>Late 2010 (estimated)</td>
<td>Expected to save 1 Mio litres fossil fuel (oil) per year and to reduce CO2 emission at around 40 Mio tons/a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kosicka kotlina (Kosice basin), Durkov area (Slovakia)</td>
<td>Electricity production</td>
<td>Kosicka kotlina (Kosice basin)</td>
<td>3 geothermal test drilled / 4 forecasted (2 doublets)</td>
<td>Between 2,100m and 3,200 m</td>
<td>50 to 70 l/s and between 125 to 135 °C</td>
<td>3.49 MWe (2 MW (net)) and 32TWh</td>
<td></td>
<td></td>
<td></td>
<td>Construction of a district heating network</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prien am Chiemsee, Germany</td>
<td>CHP</td>
<td>Southern German Molasse Basin</td>
<td>2 wells</td>
<td>between 5000 and 6000m expected</td>
<td>140°C and a flow rate between 120 to 130 l/s</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utting Bavaria, Germany</td>
<td>CHP</td>
<td>Southern German Molassis Basin (malmkarst)</td>
<td>2</td>
<td>3,600m (estimated)</td>
<td>125 °C with a flow rate of more than 165 l/s</td>
<td></td>
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</tr>
</tbody>
</table>

Source: GEOFAR
Sedimentary Hydrothermal Systems- Conclusions

• Untapped potential exists for large geothermal resources for electricity generation from sedimentary basins.
• The potential for the greatest potential energy recovery is probably in engineered geothermal systems.
• Natural permeable systems, such as permeable aquifers and natural channel permeability are the low-hanging fruit, but probably only localized.
Indian potential and perspectives
Geothermal Provinces in India

• Studied by GSI over last three decades.
• Orogenic (due to folding of crust)
  – Himalayan (NW and NE)
  – Naga-Lushai
  – Andaman-Nicobar
• Non-Orogenic
  – Cambay Graben
  – Son-Narmada-Tapti Graben
  – West Coast
  – Damodar, Mahanadi & Godavari Valleys
Around 340 hot springs were located by GSI.

Source: GSI: Spl publication no. 69, Geothermal energy resource of India, 2002

Fig. 2. Thermal springs in India.
Status of Geothermal in India

- It has been estimated that India has about 10,000 MWe of geothermal power potential

- Major Projects awarded by States
  - Puga Valley (J&K) : Thermax
    - Most attractive gradient / potential
  - Tattapani (Chattisgarh): NTPC

- Both projects are still in early stages of development
India - Prospective locations

1. Puga - Manikaran
2. Sonata - Tattapani
3. Cambay
4. Godavari
5. West Coast

Source: Web
Indian Challenges- Prospective locations

• Puga, Manikaran, Tattapani
  – Temperature
    • Drilled & recorded at shallow depth (<1 km)
    • Deeper wells / temp yet to be established
    • Need to explore deeper for high temp (> 200 C)
  – Reservoir
    • Seismic mapping for locating conducive hot reservoir
  – Remote area Logistics & Infra
    • Roads for transporting Heavy Deep drilling rigs
    • Remote areas with no local power demand
    • Power evacuation infra
  – Resource to be proven
Other locations

• ONGC best placed in Cambay and KG basin
  – Sedimentary basins explored for oil & gas
  – Hundreds of deep wells drilled
  – Reservoir description, temp gradients well known

• Challenges
  – Lower avg. gradient ~ 30 – 40 C/km
  – ~ 150 C @ 3.5 km deep
  – Identification of regions without interference with oil & gas E&P activities
ONGC Energy Centre initiatives

• Pursuing two R&D pilot projects
  • One each in Cambay and KG basin areas
    – Depth: 3500 m
    – Bottom temp: 150 C
    – Binary plant for Energy Conversion
    – Using non-flowing oil/gas wells possible

• **Cambay:** (Collaboration with Talboom, Belgium)
  – Conventional doublet: one injector one producer
  – Estimated net power ~ 2 MW

• **KG basin:** (In-house)
  – Validation of single well concept
Geothermal Pilot Project in Cambay Basin

• Gandhar (Pakhaj'an) area identified
  – Prospective 200 m thick Hazad Sand identified
  – Avg depth 3500 m
  – Avg Temp 140 deg c

• Reservoir Simulation studies for temperature sustainability carried out

• Wells identified
  – Non-flowing and no interference with oil & gas

• Action plan
  – Assess condition and test two wells for geothermal pilot suitability (as producer & injector)
  – If found suitable, implement pilot project – including ORC power plant
Single Well Geothermal

- To address challenges of extraction of geothermal energy from low permeable, high temperature sedimentary rock (KG basin), for a stand-alone well
- Initial Concept developed and simulation done
- Concept refined and simulation study being taken up.
Thank you