PRODUCTION CAPACITY OF GEOTHERMAL SYSTEMS

Gudni Axelsson - Iceland

Tianjin Workshop
May 2008
GEOTHERMAL RESOURCES

- In more than 90 countries worldwide
- Identified geothermal resources > 40,000 TWh/a
- Utilization about 130 TWh/a in 2004 [0.3%]
- **Low-temperature resources** are distributed throughout the world; they are not restricted to volcanic regions
- They are suitable for various direct applications, in particular space-heating
- Even though geothermal resources are considered renewable their **production capacity is not unlimited**; also highly variable
GEOTHERMAL RESOURCE CLASSIFICATION

- **High-temperature** if reservoir temperature at 1 km depth is above 200°C
- **Low-temperature** if reservoir temperature at 1 km depth is below 150°C
- Also on the basis of energy content [high- or low-enthalpy], physical state [liquid-dominated, two-phase or vapour-dominated] or their nature and geological setting [next slides]
CLASSIFICATION BASED ON NATURE AND GEOLOGICAL SETTING

A. Volcanic systems with the heat sources being hot intrusions or magma

B. Convective systems with deep water circulation in tectonically active areas

C. Sedimentary systems with permeable layers at great depth

D. Geo-pressured systems

E. Hot dry rock or enhanced geothermal systems

F. Shallow resources utilized through ground-source heat pump application
(B) Volcanic geothermal system
(B) Convective geothermal system
(C) Sedimentary geothermal system
PRODUCTION CAPACITY

Utilization by hot water (+steam) production, i.e. mass extraction; often large-scale and by large-capacity down-hole pumps

Production capacity of a geothermal system is predominantly controlled by the reservoir pressure decline (water level decline) caused by the hot water production

Technical limit to how great pressure draw-down can be

Also by energy content determined by temperature and reservoir size
PRODUCTION RESPONSE
(PRESSURE DECLINE)
CONTROLLED BY

- Size of geothermal reservoir
- Reservoir rock permeability
- Reservoir storage capacity (porosity + nature)
- Water recharge (i.e. boundary)
- Geological structure (fractures + main permeable volumes)
TWO MAIN TYPES OF SYSTEMS

Geothermal systems can in most cases be classified as either
(A) closed systems with limited or no recharge or
(B) open systems where recharge equilibrates with the mass extraction
## EXAMPLES OF PRODUCTION RESPONSE

<table>
<thead>
<tr>
<th>System</th>
<th>Average production</th>
<th>Water-level Decline</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laugarnes (Iceland)</td>
<td>160 kg/s</td>
<td>110 m</td>
<td>open</td>
</tr>
<tr>
<td>Laugaland (Iceland)</td>
<td>40 kg/s</td>
<td>370 m</td>
<td>semi-closed</td>
</tr>
<tr>
<td>Urban (Beijing, China)</td>
<td>~100 kg/s</td>
<td>~45 m</td>
<td>closed</td>
</tr>
<tr>
<td>Xi’an¹) (China)</td>
<td>~240 kg/s</td>
<td>~150 m</td>
<td>closed</td>
</tr>
<tr>
<td>Palinpinion (Phillipines)</td>
<td>710 kg/s</td>
<td>55 bar</td>
<td>open</td>
</tr>
</tbody>
</table>

1) Inaccurate data
See paper for details and more examples
Production- and response history of the Laugarnes system (Iceland) 1930 – 2002
Production- and response history of the Urban Area system in Beijing (China) 1979 – 2003
ASSESSMENT OF GEOTHERMAL RESOURCE PRODUCTION CAPACITY

- Volumetric assessment and dynamic modelling

- **Volumetric assessment** based on estimating reservoir energy content and assuming a likely recovery (5-20%).

- Commonly used, e.g. as first-stage assessment

- Has the **draw-back** of neglecting system response (pressure decline) by not taking permeability and recharge into account; two systems can have same energy content but highly different responses
Results of a volumetric resource assessment for the Hengill geothermal region in SW-Iceland (Monte Carlo method used)
Dynamic modelling is more powerful

Used to simulate the nature and production response of geothermal systems

Requires detailed information and data, i.e. production experience

Simple models as well as detailed numerical models (e.g. finite element models) used

Used to calculate future predictions, to estimate production capacity and for management purposes
Example of water level predictions for a production well in Beijing calculated by a numerical model; can be used to plan future utilization.
**CONCLUSIONS**

- **Pressure decline** due to production controls production capacity of geothermal systems to a large extent
- Pressure declines continuously in systems with **limited recharge**; i.e. long-term capacity is less than initial results indicate
- Nature of a geothermal system must be kept in mind when planning exploitation and during management
- **Modelling** plays a key role in understanding/management
- **Reinjection** is highly beneficial in most cases (later lectures)