The USGS National Geothermal Resource Assessment

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http://energy.usgs.gov/other/geothermal/
Outline

- Energy Issues (Greater Needs – Global Warming)
- Background on Geothermal Energy
- USGS National Resource Assessment Project
- Assessment Results
  - Identified Geothermal Systems
  - Undiscovered Geothermal Resources
  - Enhanced Geothermal Systems
- Summary
The United States faces the need to increase its electrical power generating capacity by approximately 300,000 Megawatts-electric (MWe) or 30 percent over the next 20 years.

(Energy Information Administration).
Diagram 5. Electricity Flow, 2007
(Quadrillion Btu)

Source: EIA Annual Energy Review 2007
U.S. Electric Power Generation Mix - 2

Total = 4,065 Billion KWh
Electric Utility Plants = 61.1%
Independent Power Producers & Combined Heat and Power Plants = 38.9%

- Coal: 49.0%
- Nuclear: 19.4%
- Natural Gas: 20.0%
- Petroleum: 1.6%
- Other Gases: 0.4%
- Other Renewables: 2.4%
- Hydroelectric: 7.0%
- Other: 0.3%

http://www.eia.doe.gov/cneaf/electricity/epa/figes1.html
Can geothermal help meet future electric power demands?

**Figure 7. Electricity generation by fuel, 1980-2030 (billion kilowatthours)**

- Coal
- Nuclear
- Natural gas
- Renewables
- Liquids

**Percentage Renewable Energy Consumption by the Electric Power Generation Sector derived from Geothermal Resources**

Source: EIA
On an energy-equivalent basis, CO2 emissions from geothermal use are significantly less than electricity generated using fossil fuels.

![Bar chart showing CO2 emissions per Quad Energy (Fuel) Consumed for Electric Power Generation](chart.png)
Background on Geothermal Energy

Idealized Geothermal Power System

Needs:
Heat *(Temperature)*
Fluid *(Water)*
And
Permeability *(Fractures)*

[Image of a geothermal power system diagram]

*USGS*
Background on Geothermal Energy

Electricity Generation from Geothermal Energy

Hot water flash
Steam
Binary

Source: USGS Circular 1249
Status of Geothermal Energy

1978 USGS Geothermal Resource Assessment (USGS Circular 790)
- 23,000 MWe in identified systems
- ~100,000 MWe in undiscovered systems

1978-2009 Geothermal Development
- 2500 Megawatts-electric (MWe) installed Geothermal generation capacity
- ~15,000 Gigawatt-hours (GWh) Geothermal power generated in 2005

How do 30 years of research and development alter resource estimates?
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Temperature &gt;150°C and Depth &lt;3 km for electric power production</td>
<td>Temperature &gt;90°C and Depth up to 6 km for electric power production (~75°C in Alaska)</td>
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<tr>
<td>52 identified high temperature systems</td>
<td>241 identified moderate and high temperature systems</td>
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<tr>
<td>Identified systems poorly characterized</td>
<td>Abundant exploration and production data for some systems</td>
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<tr>
<td>Idealized reservoir performance</td>
<td>Improved models for reservoir performance</td>
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<tr>
<td>Rough estimates of undiscovered resources</td>
<td>Better quantitative estimates of undiscovered resources</td>
</tr>
<tr>
<td>EGS mentioned but not estimated</td>
<td>Enhanced Geothermal Systems included</td>
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</table>
USGS National Geothermal Resource Assessment

- Mandated in Energy Policy Act of 2005
- 3-year Effort Funded in FY-2006
- DOE Support for Cooperative Projects in FY-2005-2008

- The resource assessment includes estimates of electric power production potential from:
  - Identified Geothermal Systems
  - Undiscovered Geothermal Resources
  - Enhanced Geothermal Systems (EGS)
USGS National Geothermal Resource Assessment

Assessment Components

- **Identified Geothermal Resources**
  - Moderate Temperature (90 to 150°C) or High Temperature (>150°C)
  - Liquid-dominated or Vapor-dominated
  - Producing, Confirmed, Potential

- **Undiscovered Resources**
  - Estimates Based on Mapping Potential Via Regression Analysis

- **EGS**
  - Focus on Temperature and Land Status
  - Base Estimates on History of EGS Developments and Existing Geothermal Production Experience
Geothermal Resource Categories

**Identified**
- Vapor-dominated
- Liquid-dominated
  - High-T
  - Moderate-T
  - Low-T

**Undiscovered**

Only terms highlighted in orange show complete categories. Others follow similar subdivisions (e.g., high, moderate or low temperature). By definition, undiscovered resources cannot be subdivided into producing, confirmed or potential.
Monte Carlo Simulation of Geothermal Resources

Reservoir Temperature

Recovery Factor

Reservoir Volume

Reservoir Thermal Energy

Electric Power

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~80% of systems = 90 to 150°C
~20% >150°C
Reservoir volumes of most identified geothermal systems <5 km$^3$
Identified Systems Potential –
Mean = 9057 MWe
F95 = 3675 MWe
F5 = 16457 MWe

~80% of power potential from the 20% of systems with $T_R > 150^\circ C$
Results: Identified Geothermal Systems
Identified Geothermal Systems: New Mexico

Valles Caldera (Circular 790, 1978) = 2700 MW
Unocal Initial Baca Estimates (~1980) = 400 MW with partial injection
  = 1200 MW with full injection
Our new estimate (2009) = 128 MW (including NW Sulphur Springs area)

Jemez Spring = 9 MW
Montezuma Hot Spring = 5 MW
Gila Hot Spring = 5 MW
Radium Hot Springs = 8 MW
Lightning Dock = 15 MW
Identified Geothermal Systems
Geothermal Systems and Land Status
Identified Geothermal Systems
Geothermal Systems and Land Status
The Weights-of-Evidence approach employs probability to determine the degree of correlation among spatial databases. This measure of correlation can be used to produce maps of favorability for the occurrence of features of interest. The technique has been used to study the spatial relationship of deposits to evidence layers through the use of Geographic Information Systems (GIS).

**Prior probability** – Derived from knowledge that is present before a particular observation is made.

**Posterior probability** – Derived from knowledge developed once the outcome of the observation is taken into account.

Positive and negative weights are assigned which represent the degree of correlation between evidence layers and occurrences.
Undiscovered Resources – Geothermal Favorability Maps

Warmer colors represent high probability for the presence of geothermal systems.
Undiscovered Resources – Effect of Closed Public Lands

Undiscovered Resources –
Mean = 30,033 MWe
F95 = 7917 MWe
F5 = 73,286 MWe
Enhance permeability by causing existing fractures to slip and propagate or creating new tensile cracks by raising fluid pressure.
Enhanced Geothermal Systems

- Large regions of the western US with high temperatures at depths less than 6 km.
- Thermal energy in these regions many orders of magnitude greater than thermal energy in conventional hydrothermal systems.
- High permeability required over large volume for effective thermal energy sweep.
- Stress, lithology, temperature, fluid chemistry, structure determine viability of EGS projects but roles poorly understood.
- Apply volume method using regional heat flow data, land status, and guidelines derived from EGS research projects.
Enhanced Geothermal Systems – Experimental Success

Soultz-sous-Forêts, France
Stimulated Volume ~6-8 km³
Temperature ~200℃
Potential Generation ~1.5MWe

(Tischner et al., 2007)
Enhanced Geothermal Systems – USGS Deep Temperatures

Temperature contours

Temperature contours w/o closed public lands
Enhanced Geothermal Systems – SMU Deep Temperatures

Temperature contours

Temperature contours w/o closed public lands
Enhanced Geothermal Systems (EGS)

EGS Resources –
Mean = 517,800 MWe
F95 = 345,100 MWe
F5 = 727,900 MWe

In general, USGS estimates confirm the large EGS potential identified in DOE-sponsored studies, despite differences in approach.
Distribution of Geothermal Potential

A. Identified Geothermal Resources

- California: 58.67%
- Nevada: 15.36%
- Oregon: 5.96%
- New Mexico: 1.88%
- Montana: 0.65%
- Idaho: 3.68%
- Hawaii: 2.00%
- Wyoming: 0.43%
- Washington: 0.25%
- Utah: 2.03%
- Alaska: 7.47%
- Arizona: 0.29%

B. Undiscovered Resources

- California: 37.70%
- Nevada: 14.53%
- Montana: 2.57%
- Idaho: 6.97%
- Hawaii: 8.11%
- Colorado: 3.68%
- Oregon: 6.30%
- Alaska: 5.95%
- Arizona: 3.47%
- Wyoming: 0.58%
- Washington: 1.00%
- Utah: 4.87%

C. Enhanced Geothermal Systems

- California: 9.30%
- Oregon: 12.05%
- Nevada: 19.88%
- Arizona: 10.66%
- New Mexico: 10.75%
- Colorado: 10.15%
- Idaho: 13.11%
- Montana: 3.27%
- Wyoming: 0.59%
- Washington: 1.25%
- Utah: 9.11%
Future Assessment Work

- Publish Supporting Reports and Databases
- Update Assessment Results
- Improve Enhanced Geothermal Systems Assessment Methodology
- Assess Other Unconventional Geothermal Resources
  - Geopressured Geothermal
  - Co-produced Geothermal with Oil & Gas
• The U.S. Geological Survey (USGS) has completed an assessment of our Nation’s geothermal resources in fulfillment of the mandate from the Energy Policy Act of 2005.

• Geothermal power plants are currently operating in six states - Alaska, California, Hawaii, Idaho, Nevada, and Utah – with an installed power generating capacity of more than 2500 Megawatts-electric (MWe).

• The mean electric power generation potentials are:
  • **Identified Geothermal Systems** = **9,057 MWe** (distributed over 13 states)
  • **Undiscovered Geothermal Resources** = **30,033 MWe**.
  • **Enhanced Geothermal Systems (EGS)** = **517,800 MWe** could be generated from development of the technology for creating geothermal reservoirs in regions characterized by high temperature, but low permeability, rock formations.
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