Engineering Geothermal Systems

World Wide Renewable Baseload Power

The Energy Under Our Feet
Geothermal Energy - What is it?

The deeper you go the hotter it gets
Heat Mining the Geothermal Resource
Enhanced Geothermal Systems

• Enormous resource stored as heat in rock
• Natural heat flow recharges stored heat
• Areas with high heat flow
  – Across the US
  – Around the world
Geothermal Resources in Asia

- Philippines - 1984 MW now on line
  - Total hydrothermal resource potential >30,000 MW
  - EGS resource potential >100,000 MW?
- Indonesia - 807 MW now on line
  - In development – Additional 580 MW
  - Total hydrothermal resource potential >27,000 MW
  - EGS resource potential >135,000 MW?
- Japan - 535 MW on line
  - Two major EGS experiments
  - Developed HT downhole pump for EGS through Ebara
  - Large scale EGS potential
Geothermal in Japan: EGS Potential

- Location of Geothermal and Nuclear Power Plants, Hot Springs, and Volcanoes
- Geothermal Gradient and Heat Flow
- Location of EGS sites: Hijori and Ogachi
- Geologic Mapping of Faulting and Plutonic Rocks

Geothermal and Nuclear Power Plants in Japan

http://upload.wikimedia.org/wikipedia/commons/thumb/1/1e/Geothermal_power_plants_in_Japan_E.PNG/350px-Geothermal_power_plants_in_Japan_E.PNG

Active Volcanoes

Hot Springs

http://www.eri.u-tokyo.ac.jp/COV5/images/map_japan.gif

http://www.infomapjapan.com/images/spfeature/200612/onsen_map.gif
Economics
High Temperature System

300° C at 4 km
• With current technology ~7.8¢/kWh
• With improved technology 5.4¢/kWh
• Areas for technology improvement
  – Conversion cycle efficiency
  – Drilling cost reduction/risk reduction
    • Fewer casing strings
    • Higher hard rock ROP
    • Better measurement while drilling for HT (risk↓)
  – Improved stimulation technology
    • Better zone isolation
    • Better reservoir understanding
      – Stress measurement
      – Fracture ID
      – Higher flow per producer
      – Single well test methods
EGS Advantages

- Enormous un-tapped energy resource for baseload power generation
- Only baseload renewable energy source scalable to large capacity projects.
- Significant U.S. reserves located in areas of power demand
- Zero emissions
- Low operating cost.
- No fuel cost
- Small plant footprint
- Widely distributed
- Much greater availability than wind and solar >95%
- Long project lifespan up to 30 or more years
- CO₂ sequestration potential
- Reduce cost and improve performance using CO₂ in the reservoir
- 1 km³ of rock cooled 20° C = 29,300,000 BBLs oil equivalent