Engineering Geothermal Systems

World Wide Renewable Baseload Power

The Energy Under Our Feet

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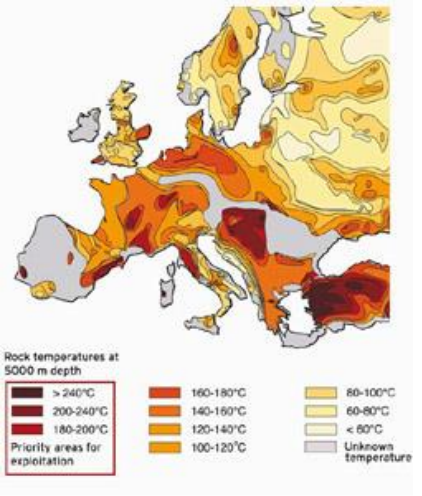
Geothermal Energy – What is it?

The deeper you go the hotter it gets

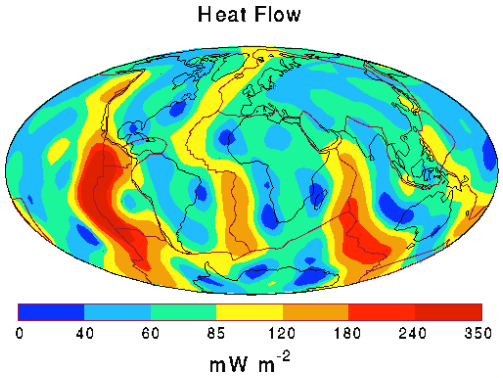
Heat Mining the Geothermal Resource

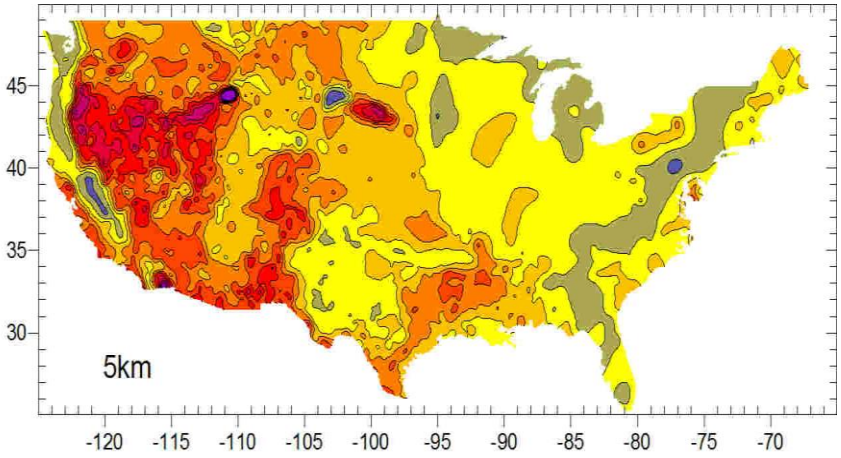
Enhanced Geothermal Systems

- Enormous resource stored as heat in rock
- Natural heat flow recharges stored heat
- Areas with high heat flow
  - Across the US
  - Around the world



Rock temperatures at 5 km depth





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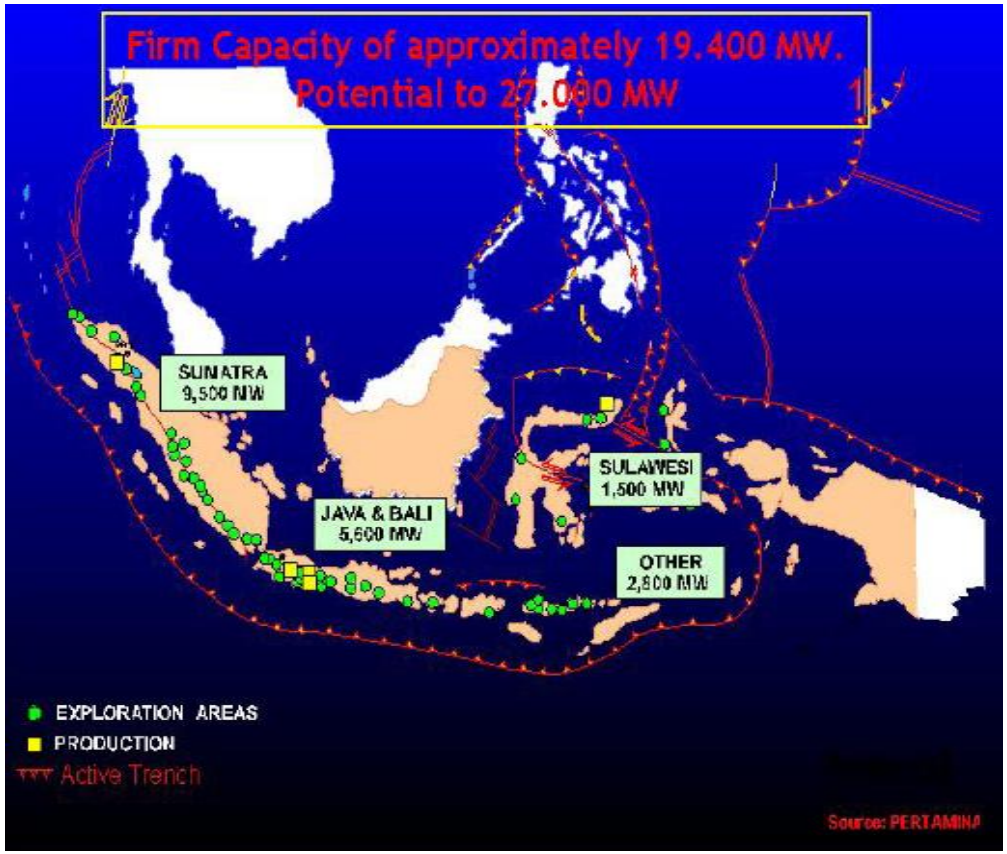
Geothermal Resources in Asia

- 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



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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

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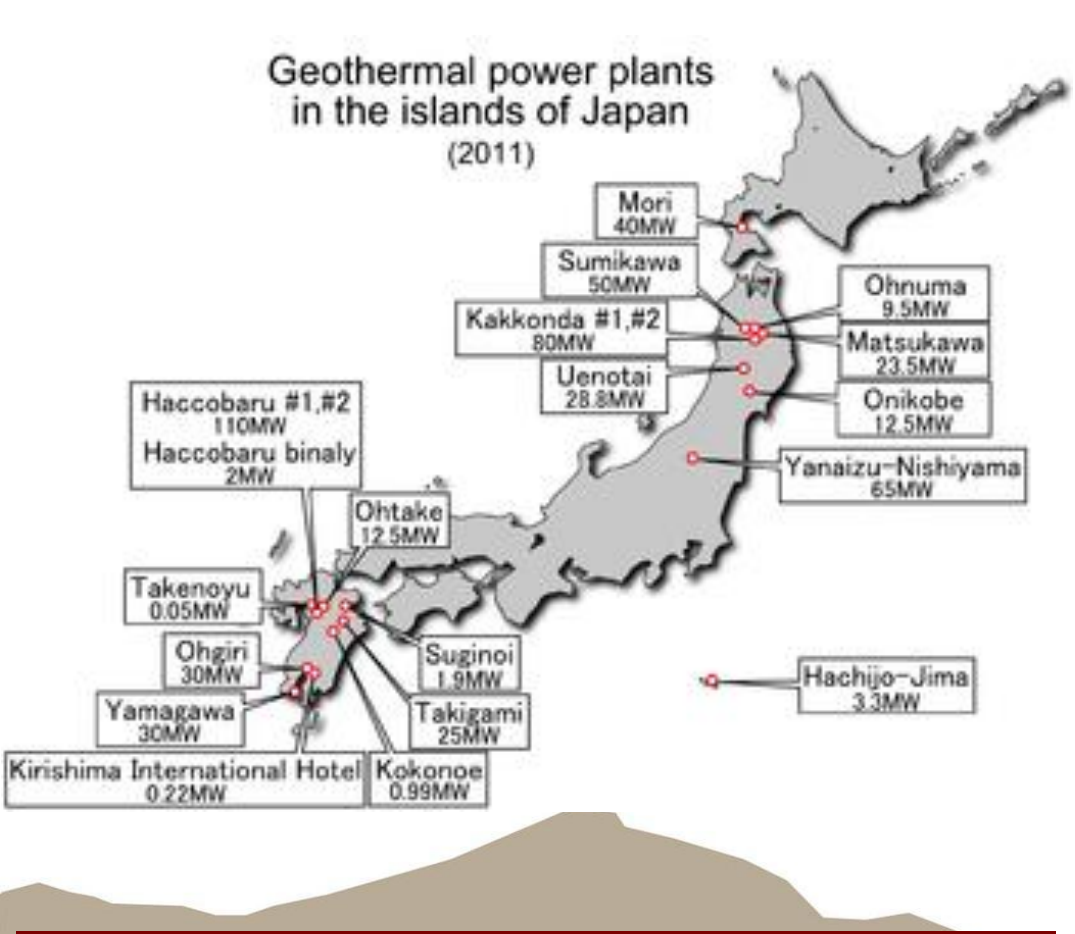
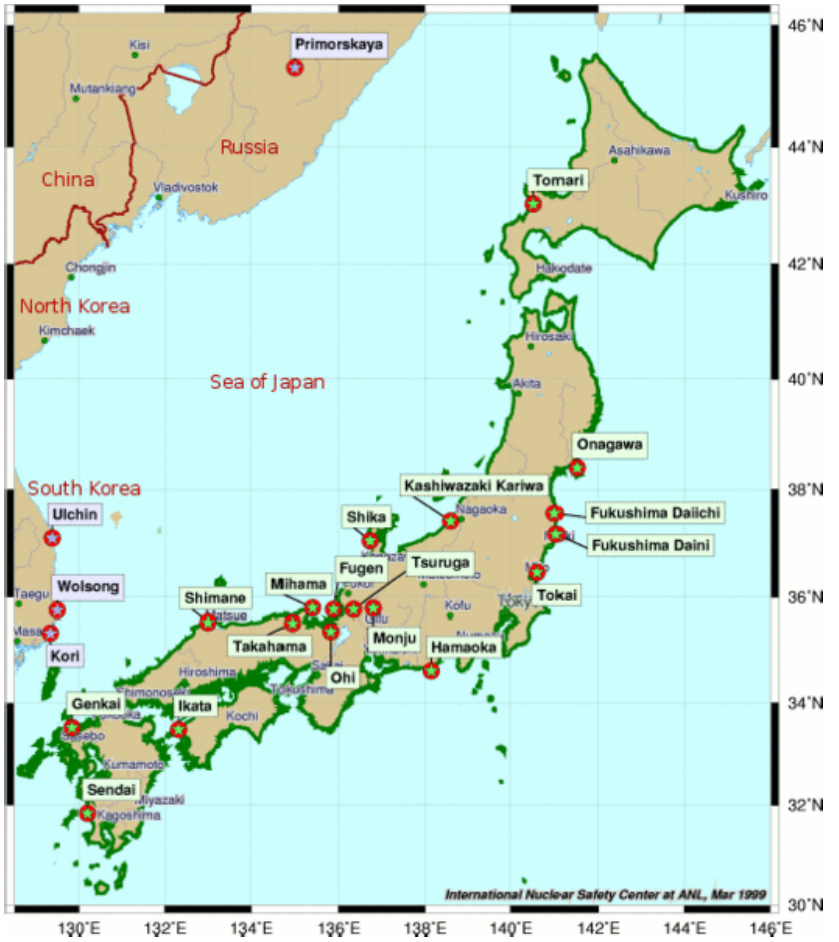
http://adventures.bootsnall.com/img/trips/1589-japan-tokyo-japan-essential-kyoto-mt-fuji-tokyo.jpg

Geothermal and Nuclear Power Plants in J

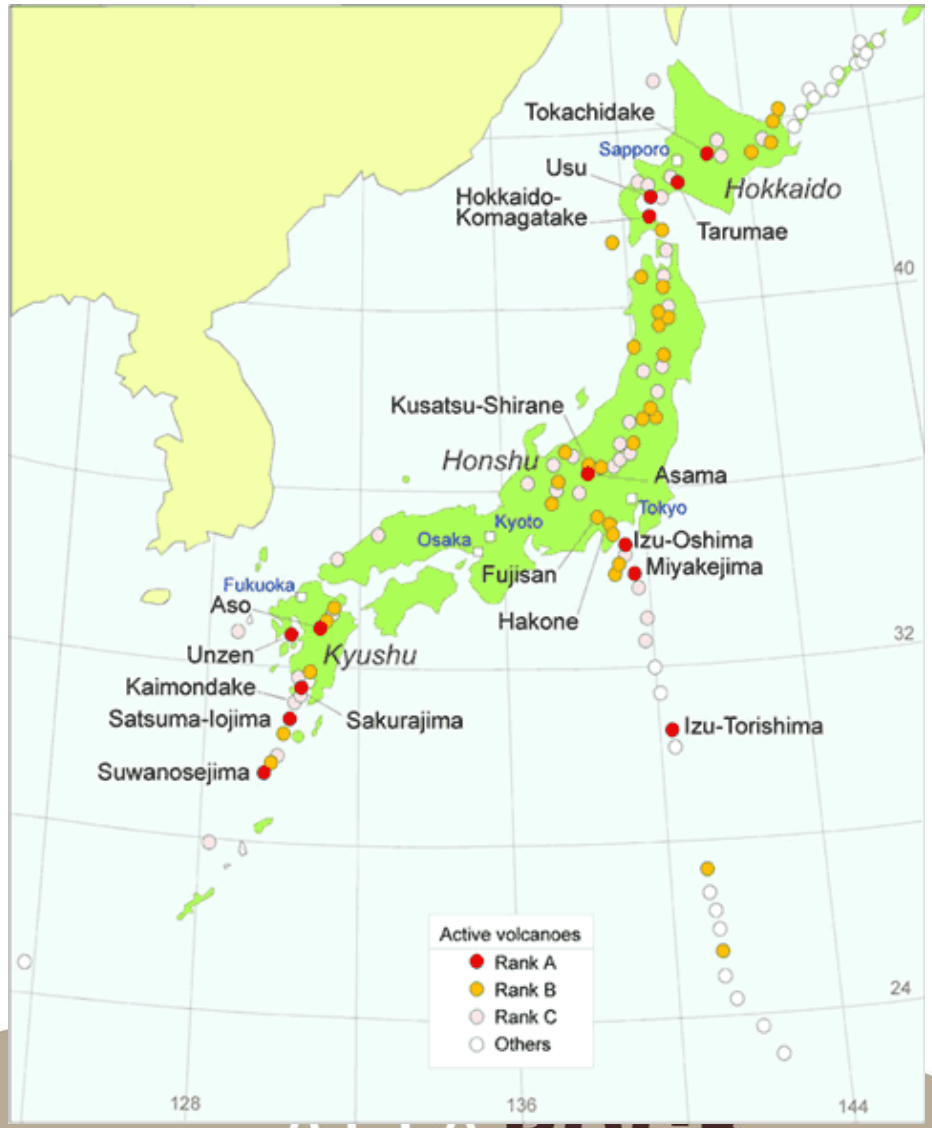


http://upload.wikimedia.org/wikipedia/commons/thumb/1/1e/Geothermal_power_plants_in_Japan_E.PNG/350px-Geothermal_power_plants_in_Japan_E.PNG



http://modernsurvivalblog.com/wp-content/uploads/2011/03/japan-nuclear-reactor-map.gif

Active Volcanoes



Hot Spring

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

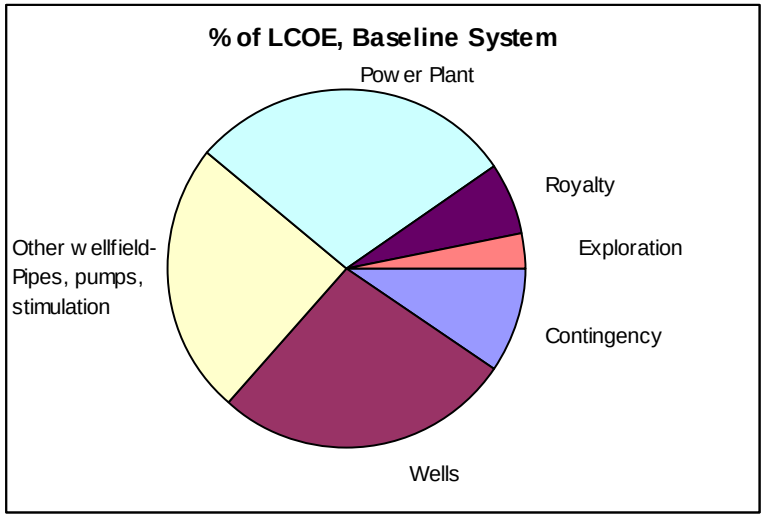
http://www.infomapjapan.com/images/spfeature/200612/onsen_map.gif

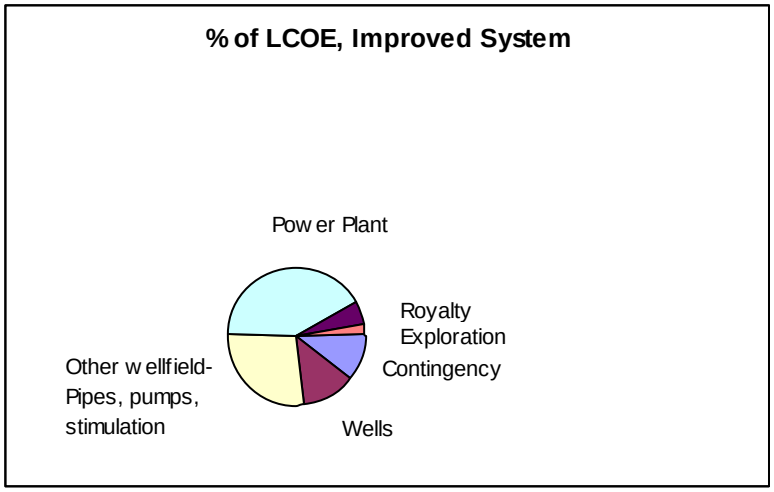
Economics

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
- CO_2 sequestration potential
- Reduce cost and improve performance using CO_2 in the reservoir
- 1 km^3 of rock cooled 20° C = 29,300,000 BBLs oil equivalent