Geothermal Electric Power

Chuck Kutscher
NREL
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Advantages of Geothermal Energy

- Environmentally sound
- Resources last the life of the plant
- High plant availability (over 95%)
- Provides steady base load power
- Relatively low cost (4 to 8 cents per kWh)
Geothermal Domains

- Saturation
- Permeability
- High Temperature

Enhanced Geothermal System

- Fracturing Required
- Water Injection Required
- Fracturing and Water Injection Required

Note: Must Have Mobile water, Heat And Permeability To Have a Potentially Viable System. This Combination Can be Natural (Hydrothermal System) or Created (an EGS System –Must always Have Hot Rock, Can Then Fracture And Inject Water)
Hottest Known Geothermal Regions
Geothermal Power Plants
Today’s Plants

- 8,000 MWe being generated in 21 countries
- 22 plants in U.S. (mostly California and Nevada) providing 2,200 MWe
- Hydrothermal resources could provide additional 20,000 MWe in U.S., 75,000 MWe in developing nations; hot dry rock resource is immense
5-10K MW
Estimated
Developable
Resource
By 2010

Power Production

Direct Uses

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Geothermal Energy

Installed Capacity

Installed:
- About 2800 MW (electric)
- Over 600 MW (heat)
- 400 MW under development (electric)

- Salton Sea (under development) - 100 MW
- Glass Mountain (under development) - 100 MW
- Steamboat (under development) - 40 MW
- Sulfur Hot Springs (under development) - 25 MW
- Ormat (under development) - 30 MW
- Raft River (under development) - 10 MW

- Greater Than 20 MW
- Less than 20 MW
Plant Type vs. Temperature

- Flash steam
  - 175°C (350°F)
- Binary cycle
  - 90°C (195°F)
Flash Steam Power Plant

- **Turbine**
- **Steam**
- **Brine**
- **Water**
- **Cooling Tower**

Producers and Injectors:
- **Production Well**
- **Injection Well**

Geothermal Zone:
- **Air and Water Vapor**
- **Air**
- **Waste Brine**

Production of **Steam** and **Injection of Water**.
Binary Cycle Power Plant

- Generator
- Iso-Butane Production Well
- Injection Well
- Geothermal Zone
- Water Heat Exchanger
- Air and Water Vapor
- Air Pump
- Cool Brine Condenser
- Cooling Tower
# Plant Costs

<table>
<thead>
<tr>
<th></th>
<th>Flash ($/kW)</th>
<th>Binary ($/kW)</th>
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<tbody>
<tr>
<td>Exp./drilling</td>
<td>700</td>
<td>500</td>
</tr>
<tr>
<td>Equip.</td>
<td>750</td>
<td>1600</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,450</strong></td>
<td><strong>2,100</strong></td>
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DOE Role

- R&D and deployment activities to enable US industry to expand geothermal energy use

- Priorities are exploration and drilling to reduce risks and up-front costs. Immediate gains anticipated from enhanced conversion technology

- Goal is 20,000 MW$_e$ hydrothermal and 20,000 MW$_e$ enhanced geothermal plants by 2020
Geothermal Program Strategic Thrusts- 6 National Labs Involved

**Drilling**
- Advanced Drilling System
- High-speed data link

**Exploration**
- Integrated geophysical methods
- 3-D seismic analysis

**Reservoir Engineering**
- Enhanced Geothermal Systems
- Tracer injection experiments

**Energy Conversion**
- Small modular power systems
- Improved heat rejection
- Kalina cycle demonstration
NREL Energy Conversion Research
# Potential Impacts of Power Plant R&D

<table>
<thead>
<tr>
<th>Area</th>
<th>Improvement</th>
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<tbody>
<tr>
<td>Heat exchangers</td>
<td>8% – 10%</td>
</tr>
<tr>
<td>Cycle efficiency</td>
<td>5% – 7%</td>
</tr>
<tr>
<td>Off-design enhancement</td>
<td>3% – 5%</td>
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<tr>
<td>Reduced O&amp;M</td>
<td>2% – 3%</td>
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Conceived and developed the R&D-100 award winning Advanced Direct Contact Condenser
Fluent Analysis: 3 Rows of Tubes
Flow Comparison: Plain Fins vs. Tabbed Fins

Plain

Tabbed
SRC Prototype High-Performance “t-fin” Heat Exchanger
Power Production with Evaporative Pre-cooling

Total Kilowatt-hours Produced

- No Enhancement
- Spray Cooling
- Munters Cooling
- Deluge Cooling
- Hybrid Cooling
Field Measurements

Munters system

Hybrid system
Heat Exchanger Coatings

- NREL-BNL-industry partnerships
- Cost-effective thermally conductive polymer coating (PPS composite liner with a zinc phosphate primer) protects carbon steel tubes
- Developed through lab and field tests

PI: T. Sugama, BNL
PI: K. Gawlik, NREL
Innovative Cycles Research

• Aimed at lower temperature resources, especially suitable for enhanced geothermal systems

• Should exceed efficiency of simple binary cycles at lower cost

• Prefer robustness, simplicity, environmental friendly cycles

• Building 1.3 MW mixed hydrocarbon working fluid plant, analyzing other cycles
Analysis Support

- Cost trends in geothermal
- Production tax credit report
- By-product value
- Program emphasis

PI: W. Short, L. Vimmerstedt, NREL
Promoting Geothermal Energy through Outreach Materials and Activities

Beautiful products for the Program

PI: B. Green, NREL
Technology Summary

- Clean, reliable base load power
- Large plants ~5 cents/kWh, small plants ~7 cents/kWh
- R&D underway to reduce risks and costs
- Expect renewed interest with production tax credit
Direct Uses and Geothermal Heat Pumps
Direct Uses

- Balneology (hot spring and spa bathing)
- Agriculture (greenhouse and soil warming)
- Aquaculture (fish, prawn, and alligator farming)
- Industrial Uses (product drying and warming)
- Residential and District Heating
Worldwide Geothermal Direct Use

- Direct uses of geothermal water supply over 11,000 thermal megawatts in over 40 countries.

- Another 35 countries use natural hot springs for bathing but have not yet developed their geothermal reservoirs for commercial use.
District Heating in Western U.S.

- There are 18 district heating systems operating in the western United States.
- Over 270 cities in the western U.S. are close enough to geothermal reservoirs to use district heating.
Geothermal Heat Pumps

- Use ground as source/sink for a heat pump instead of air
- $7,500 for 3-ton system compared to $4,000 conventional furnace/AC
- 2-10 year payback
- 500,000 systems in U.S. today
Heat Pump in Winter

Heat is collected from underground & transferred to the building
Heat Pump in Summer

Heat is collected from the building & transferred to the ground.