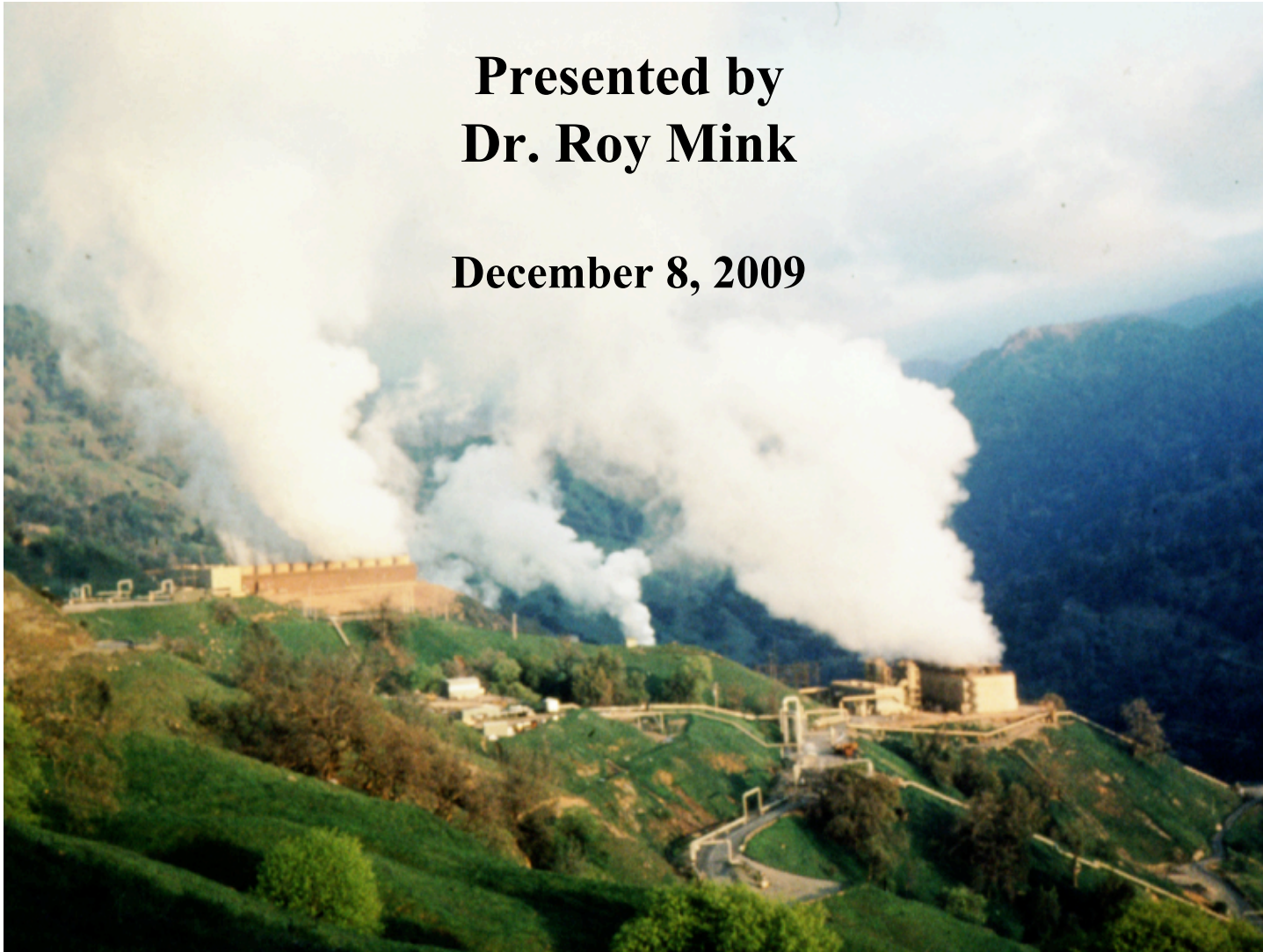


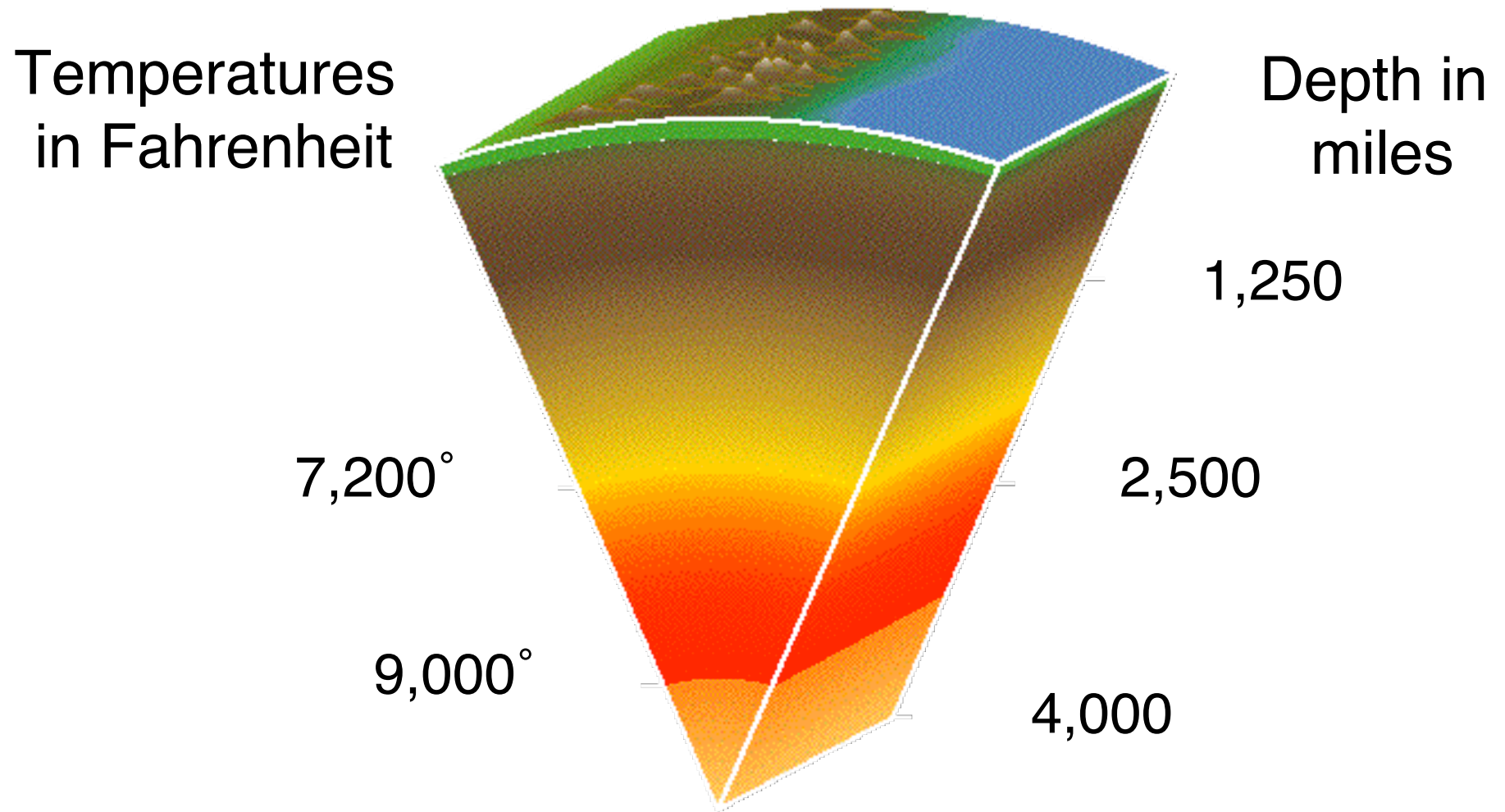
Geothermal Overview

**Presented by
Dr. Roy Mink**

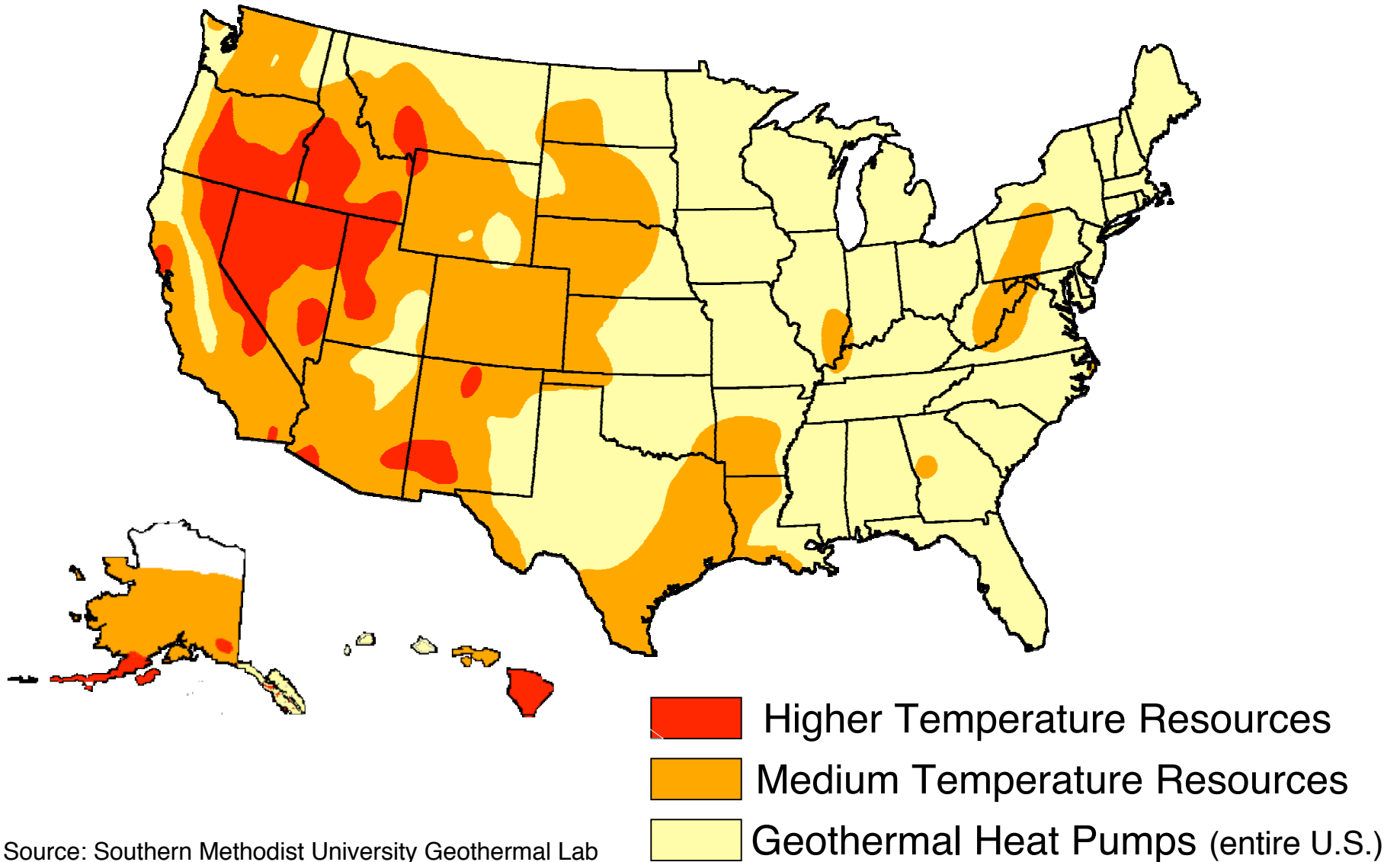
December 8, 2009



Temperatures in the Earth

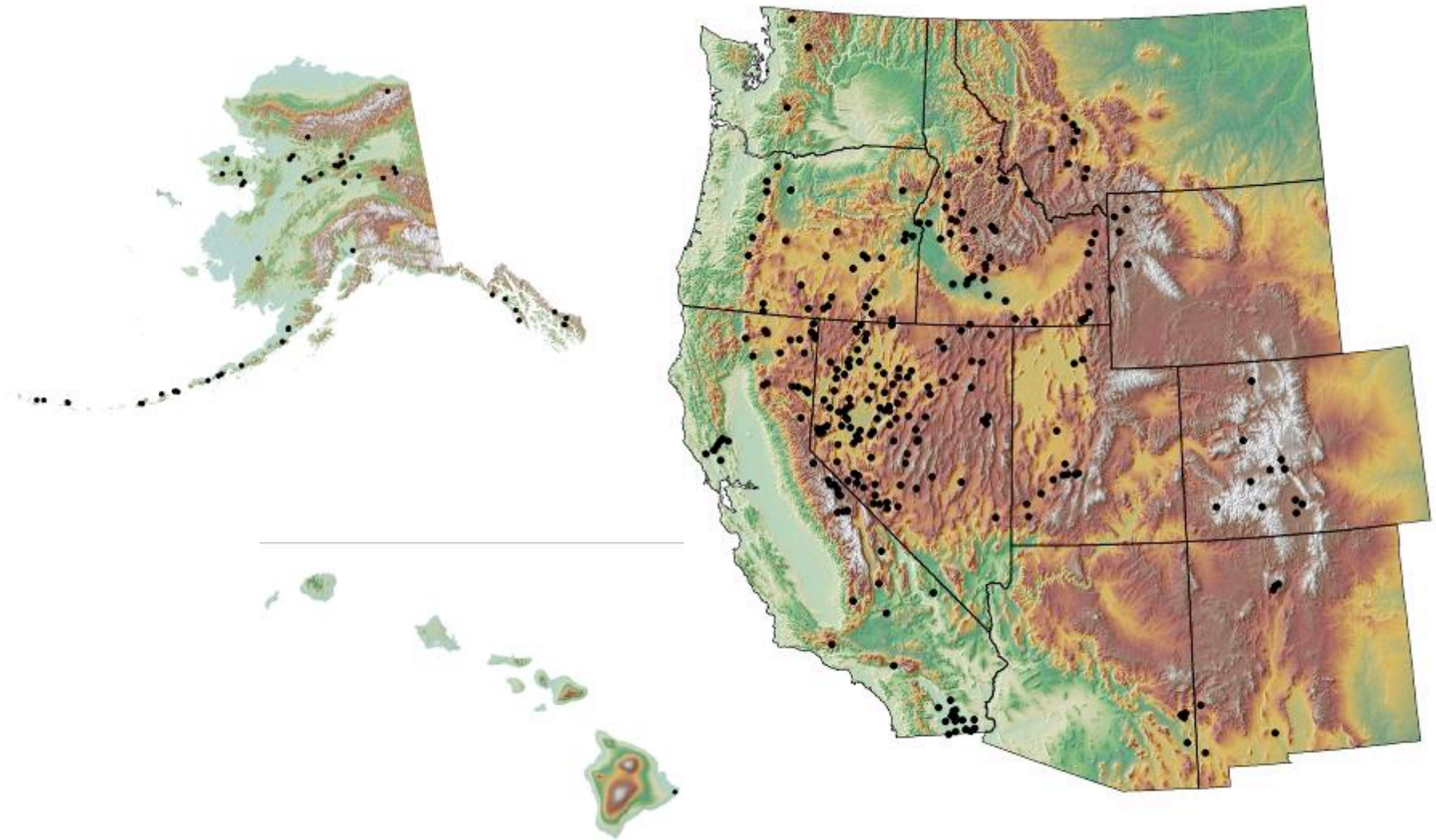


U.S. Geothermal Potential



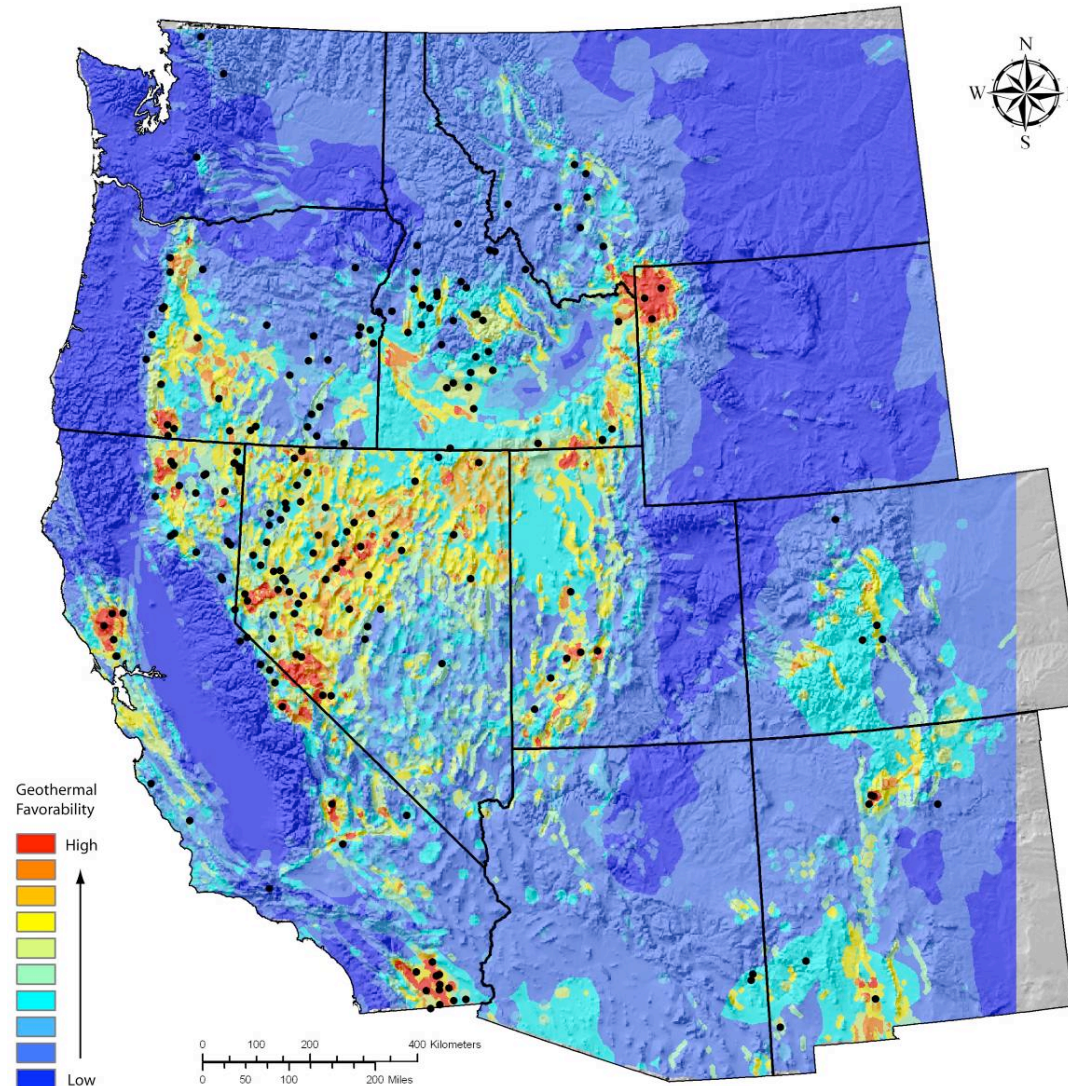
Areas in red and orange are where, with today's technology, we can find and use geothermal reservoirs.

Identified Geothermal Systems



Undiscovered Resources Geothermal Favorability Maps

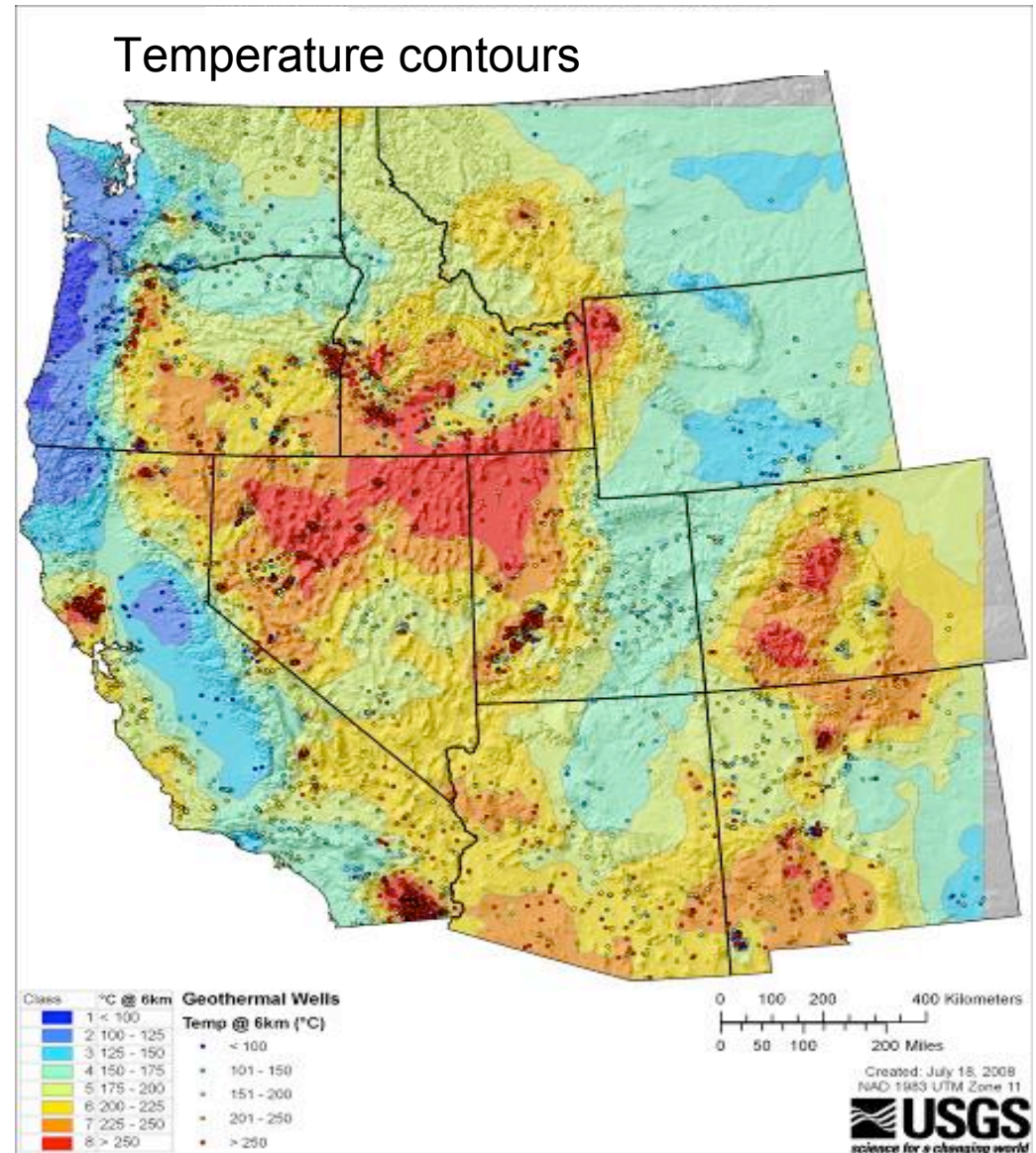
Warmer colors represent high probability for the presence of geothermal systems



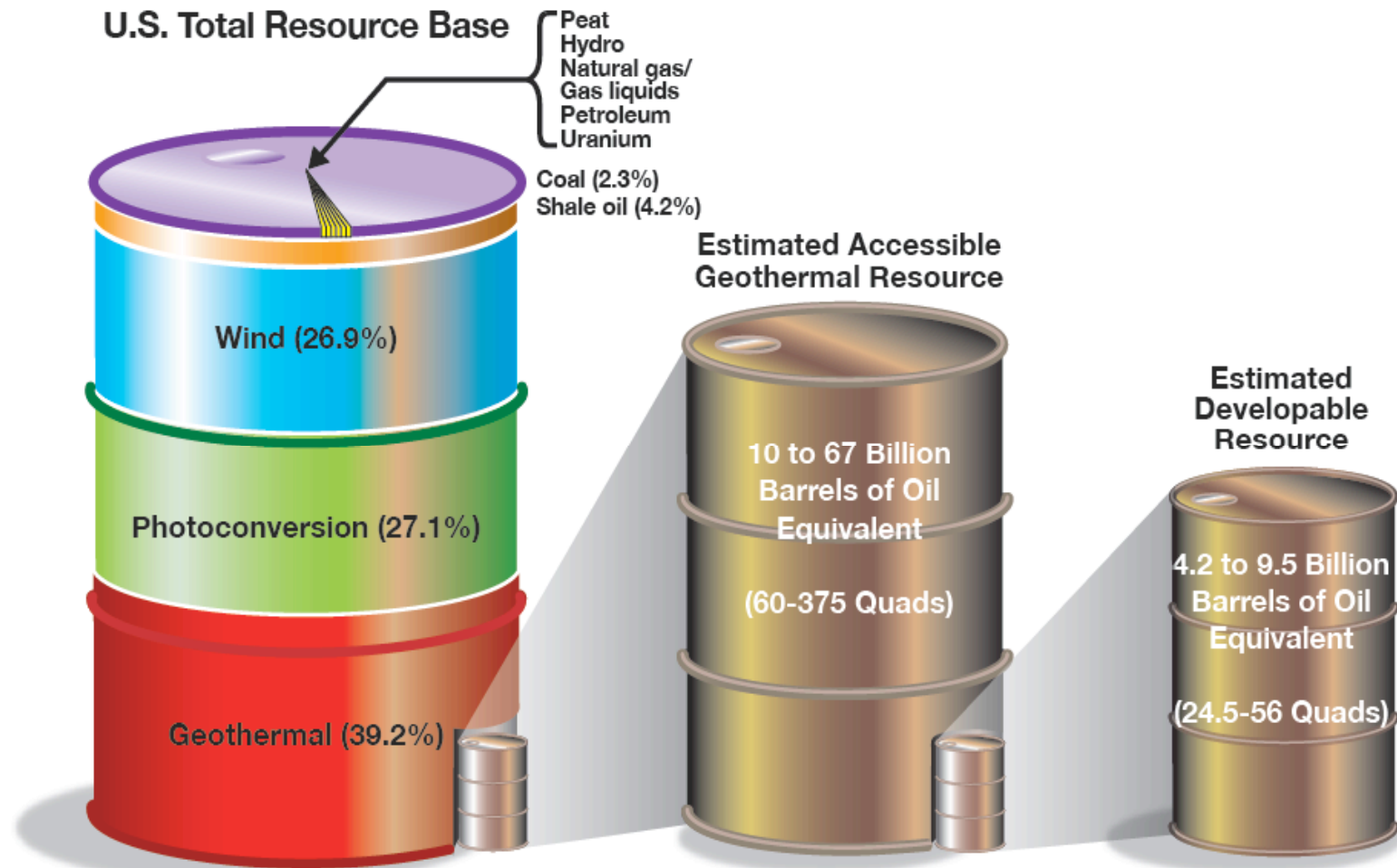
Enhanced Geothermal Systems (EGS) – Temperatures at Depth and Resource Estimates

EGS Resource –

In general, USGS results confirm earlier DOE-sponsored studies, with an estimate of ~500,000 MWe.



U.S. Energy and Geothermal Resources

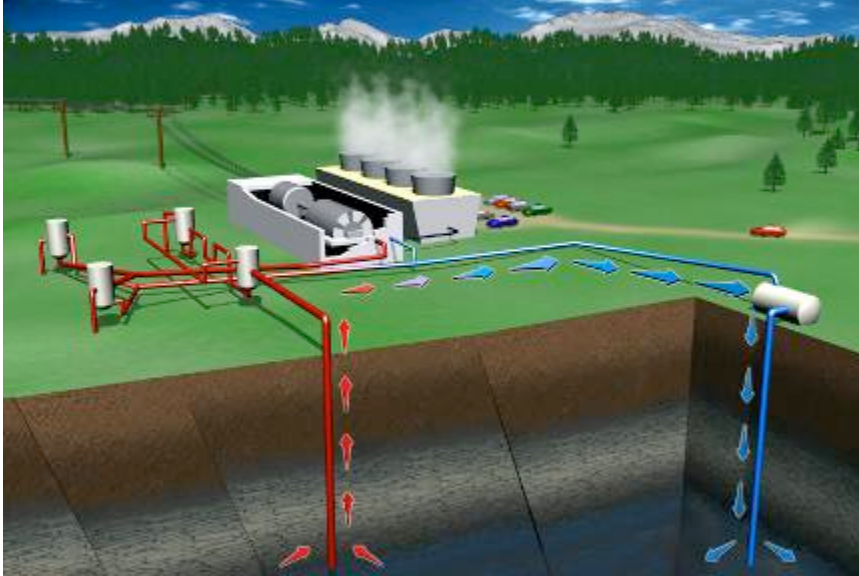


Source: *Characterization of U.S. Energy Resources and Reserves*, December 1989, U.S. Department of Energy, DOE/CE-0279.

Current Geothermal Energy in the U.S.

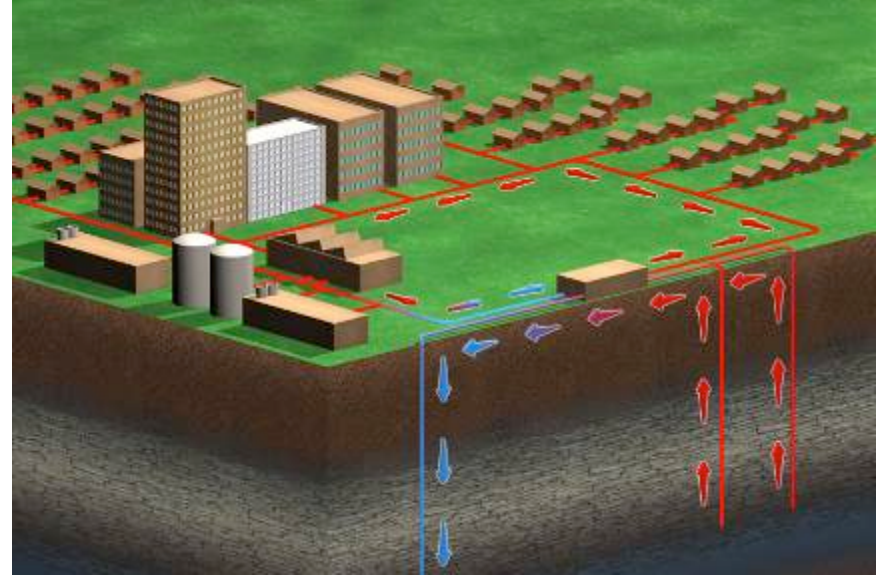
- 2,800 megawatts of **electricity** supply 4 million people in the western U.S. and Hawaii
- 500 thermal megawatts used for **direct use**
- 1,000,000 **heat pumps** nationwide, providing 3,750 thermal megawatts of heating and cooling

Geothermal Energy Technologies



Electricity Generation

- Distributed Power
- Central Station Power



Heat Production

- District Heating
- Process Heat
- Agriculture
- Aquaculture

Geothermal Systems

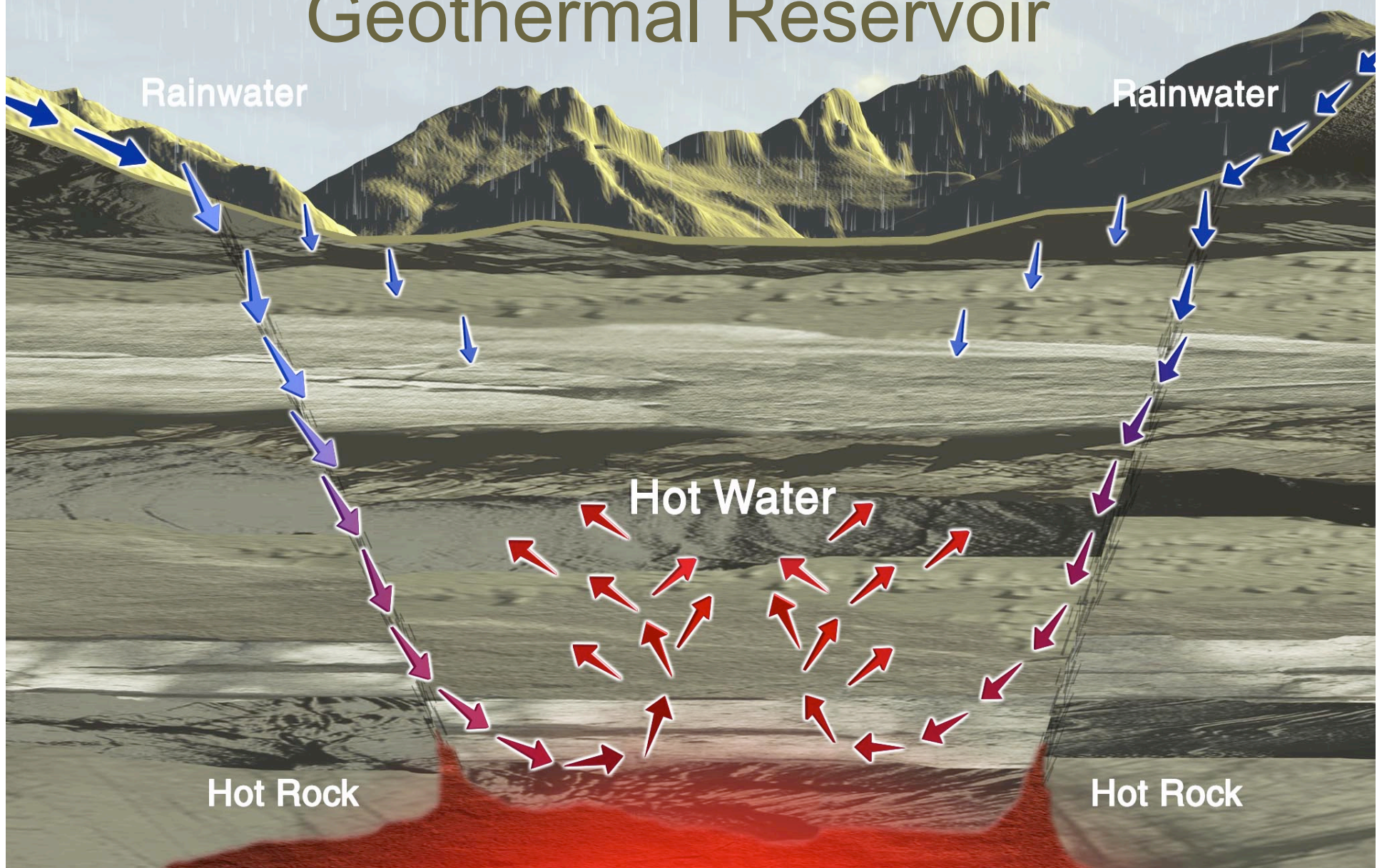
Low Temperature

- Direct Use
 - District Heating
 - Bio-fuels Production
 - Greenhouse
 - Aquiculture
 - Agriculture
 - Process Heat
 - Geothermal Heat Pump

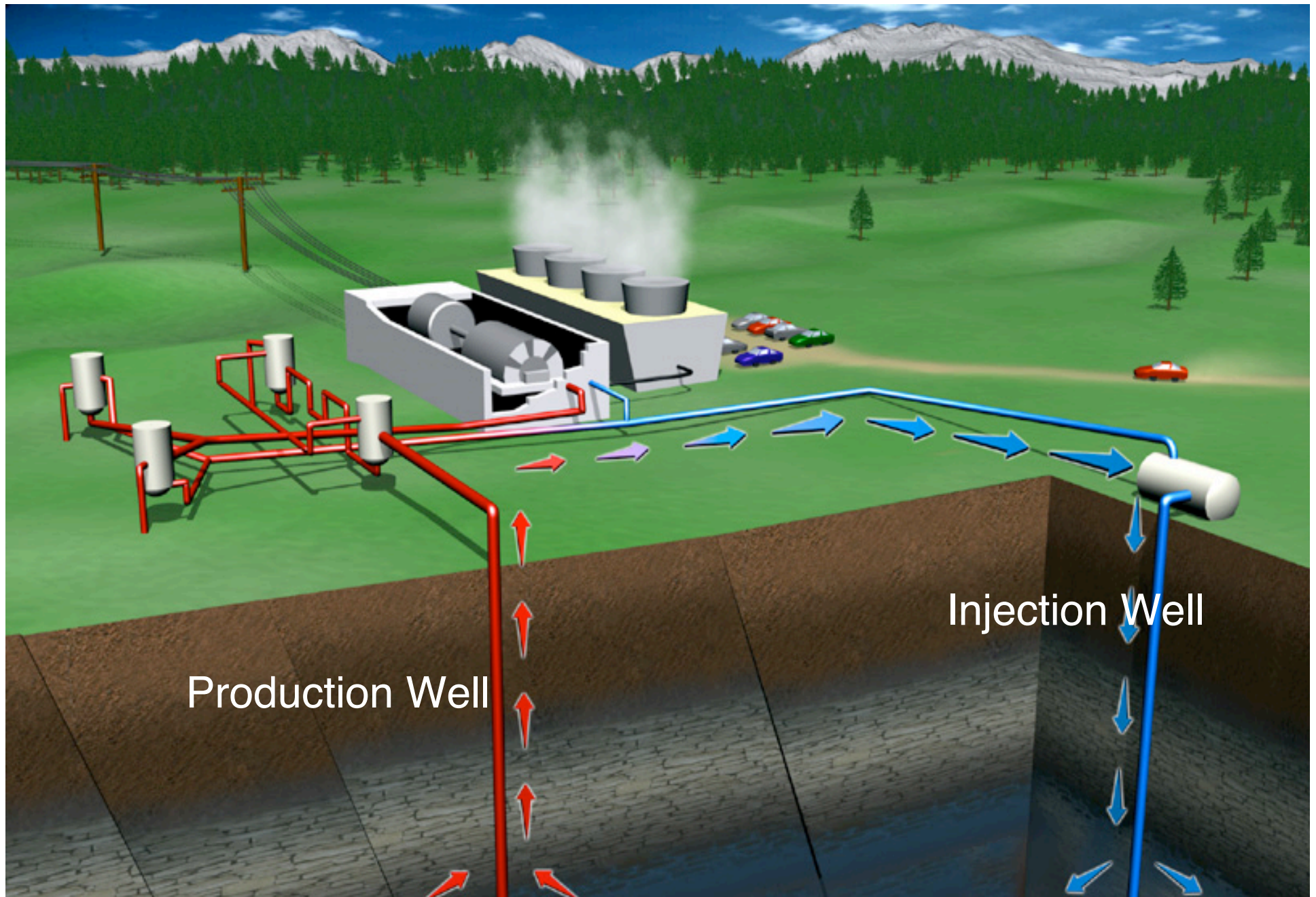
High Temperature

- Power Systems
 - Flash
 - Binary
- Other Applications
 - Distributed Power
 - Mineral Recovery
 - Hydrogen Production

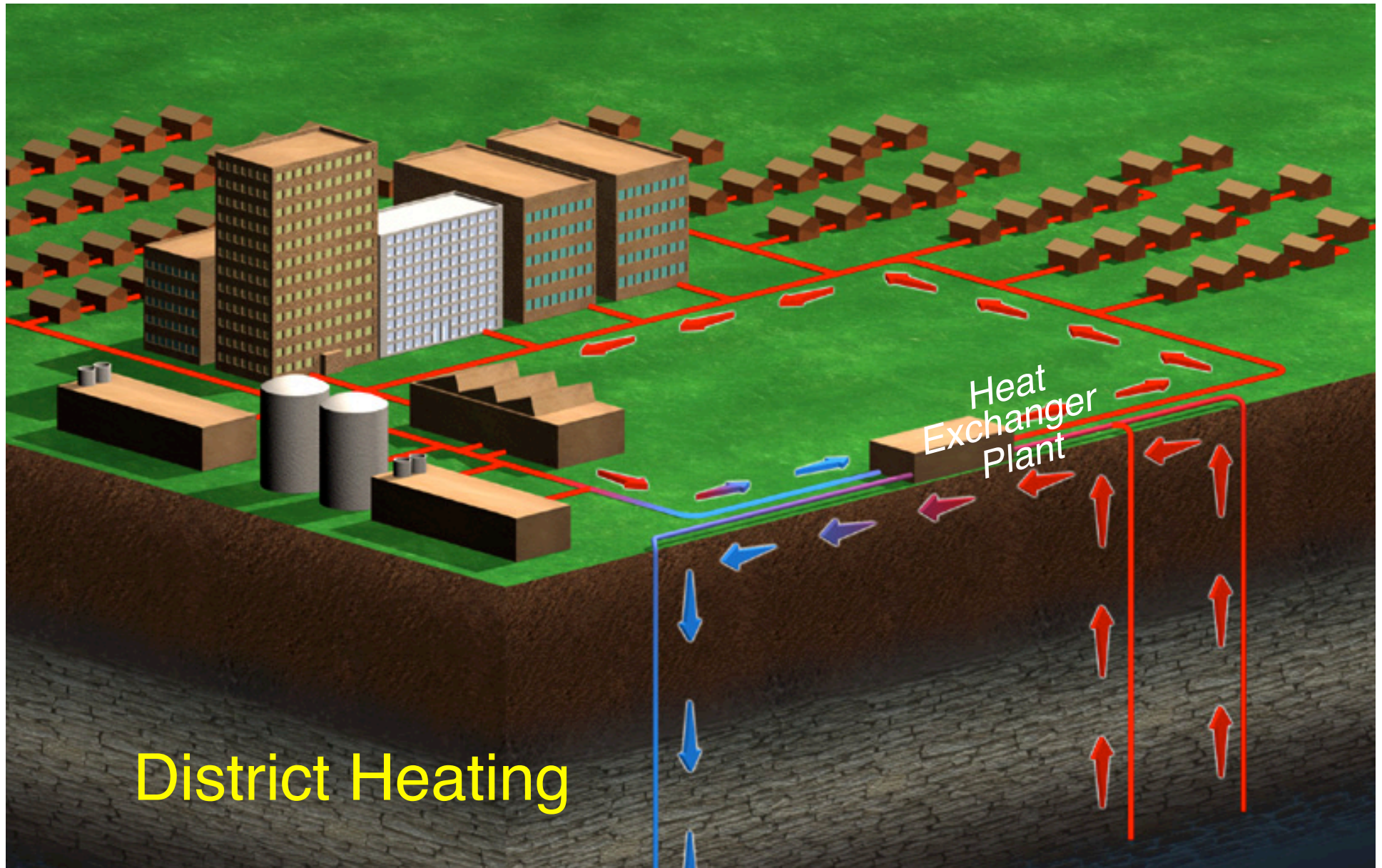
Geothermal Reservoir



When the hot water and steam accumulate in permeable and porous rock, a geothermal reservoir forms.



Natural steam from the production well powers the turbine generator. Condensed steam and unused hot water are injected back into the reservoir, thus sustaining production.

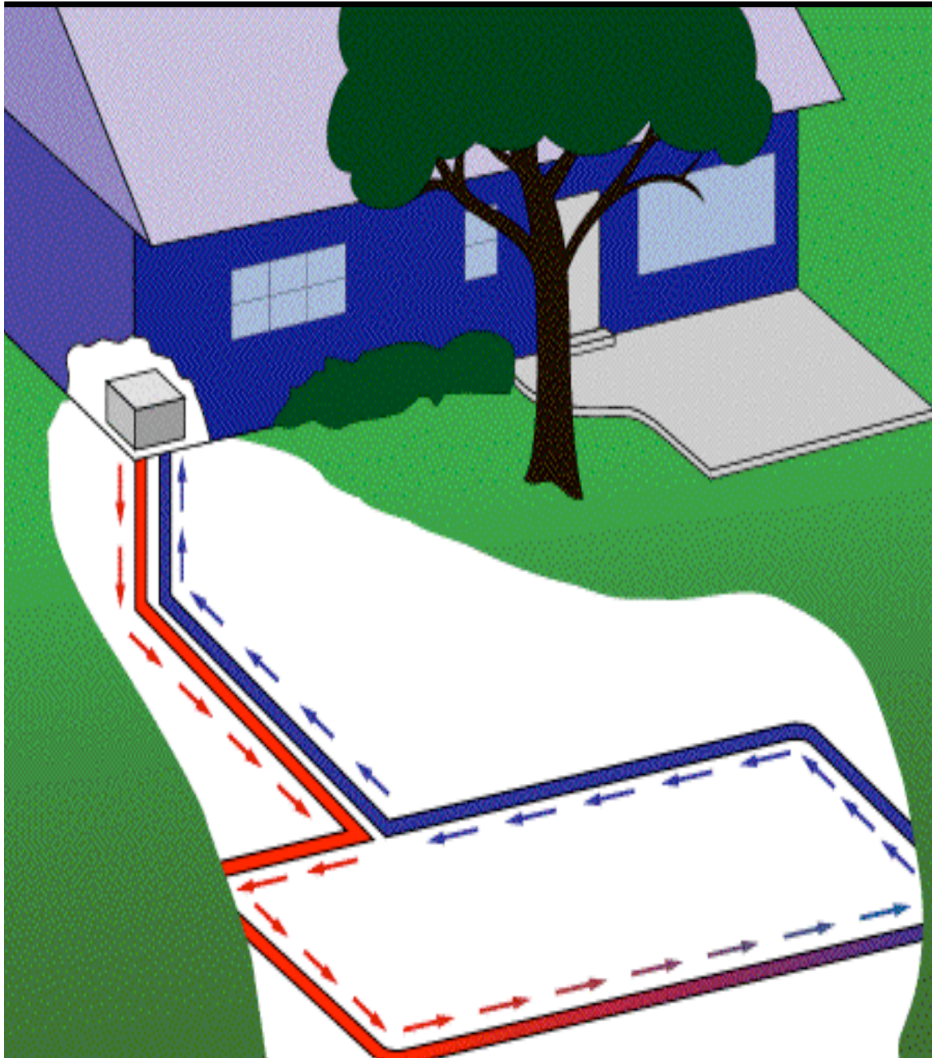


District Heating

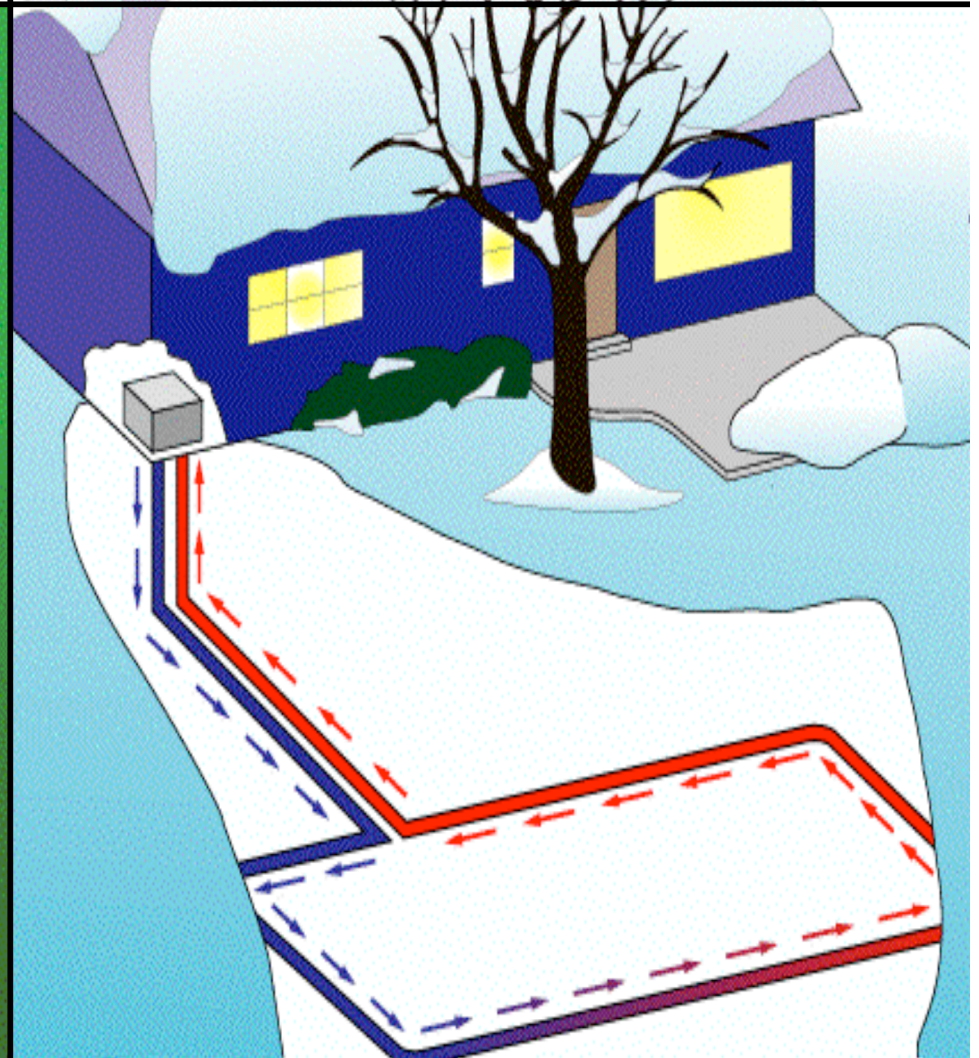
In a geothermal district heating system, hot water from one or more geothermal wells is piped through heat exchanger plant to heat city water.

The hot city water is then used to heat the buildings.

Heat Pump Summer Cooling

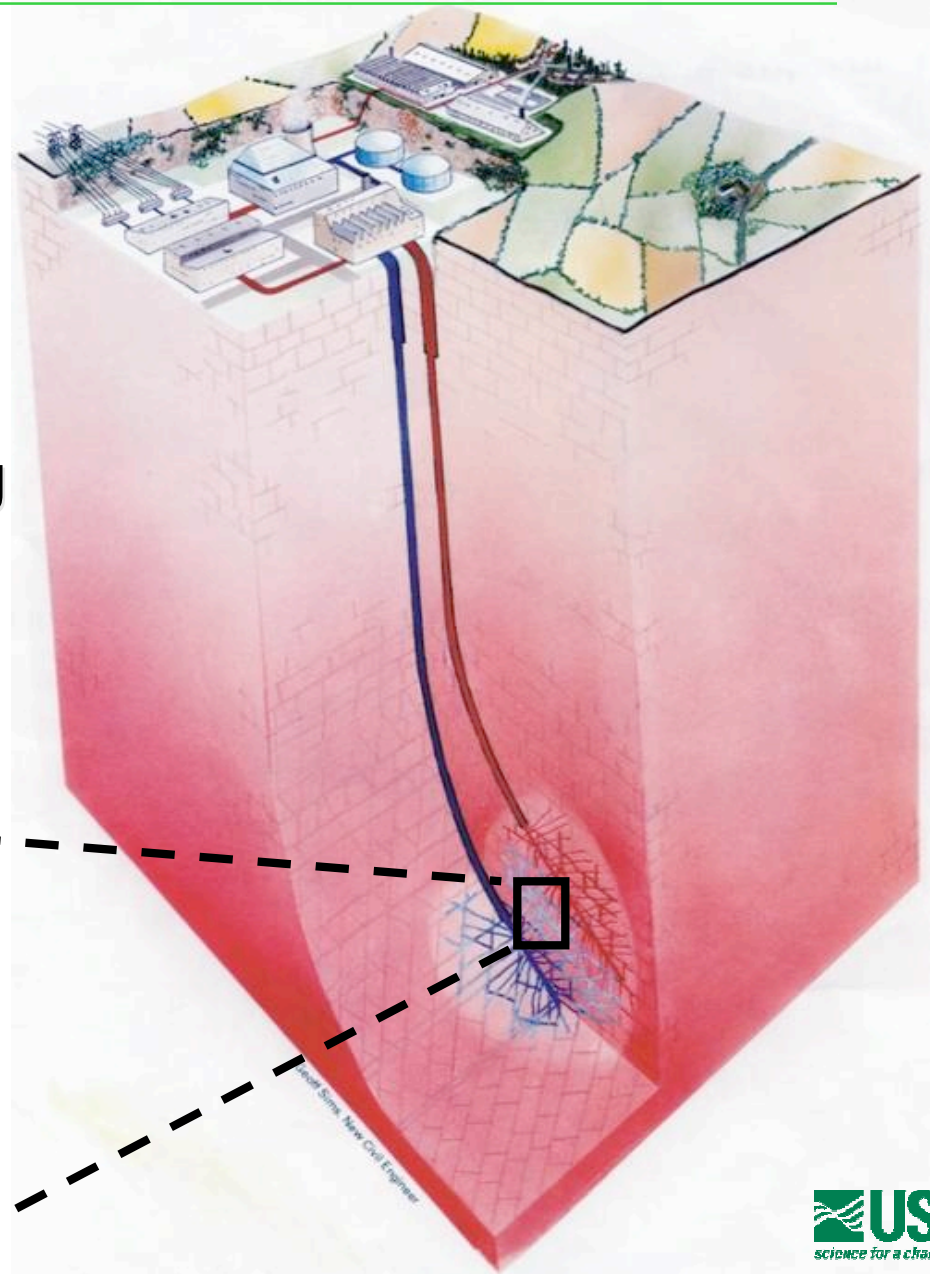
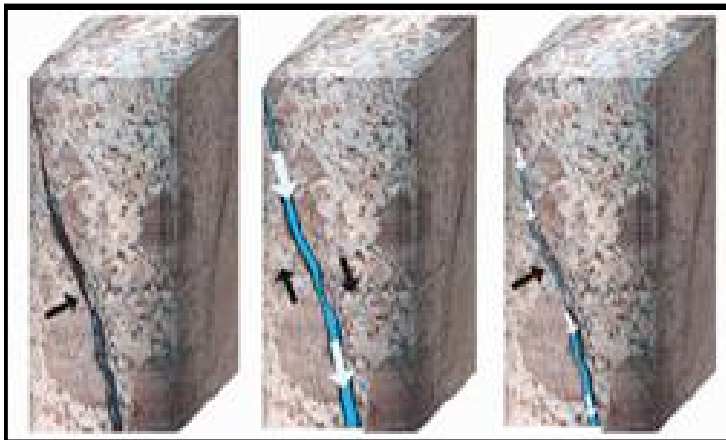


Heat Pump Winter Heating

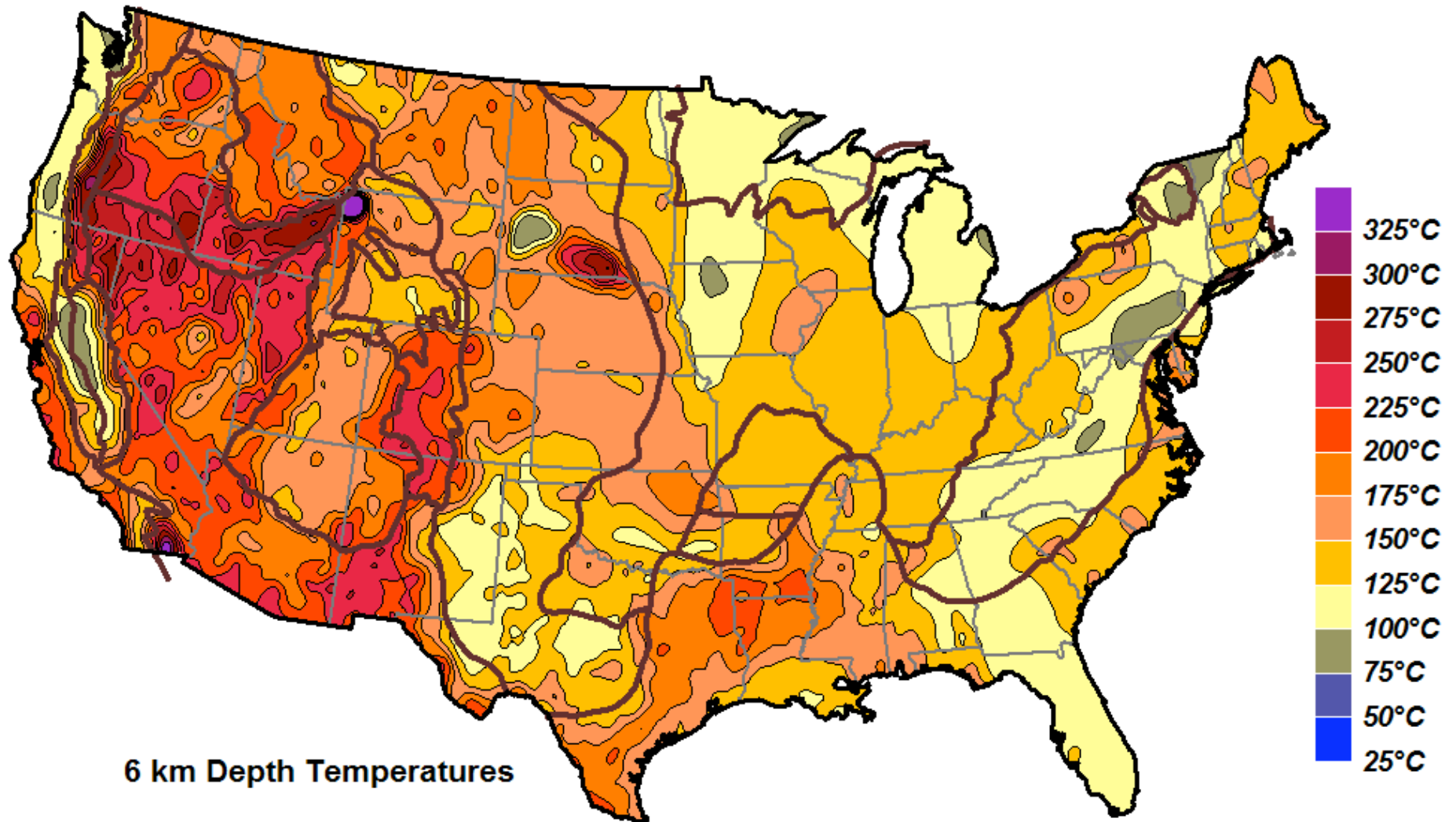


Enhanced Geothermal Systems (EGS)

Enhance permeability by causing existing fractures to slip and propagate or creating new tensile cracks by raising fluid pressure



Enhanced Geothermal Systems



Source: Blackwell and Richards (June, 2007)

Geopressure Energy Potential



Major Sedimentary Basins – North America

Billions of bbl of water produced from oil fields, some of it hot enough to be used for geothermal.

Question is how much can actually be utilized?



Co-produced Geothermal - Oil & Gas

At the Rocky Mt. Oil Test Center in Wyoming, electricity is being produced from hot water that is brought up with petroleum.

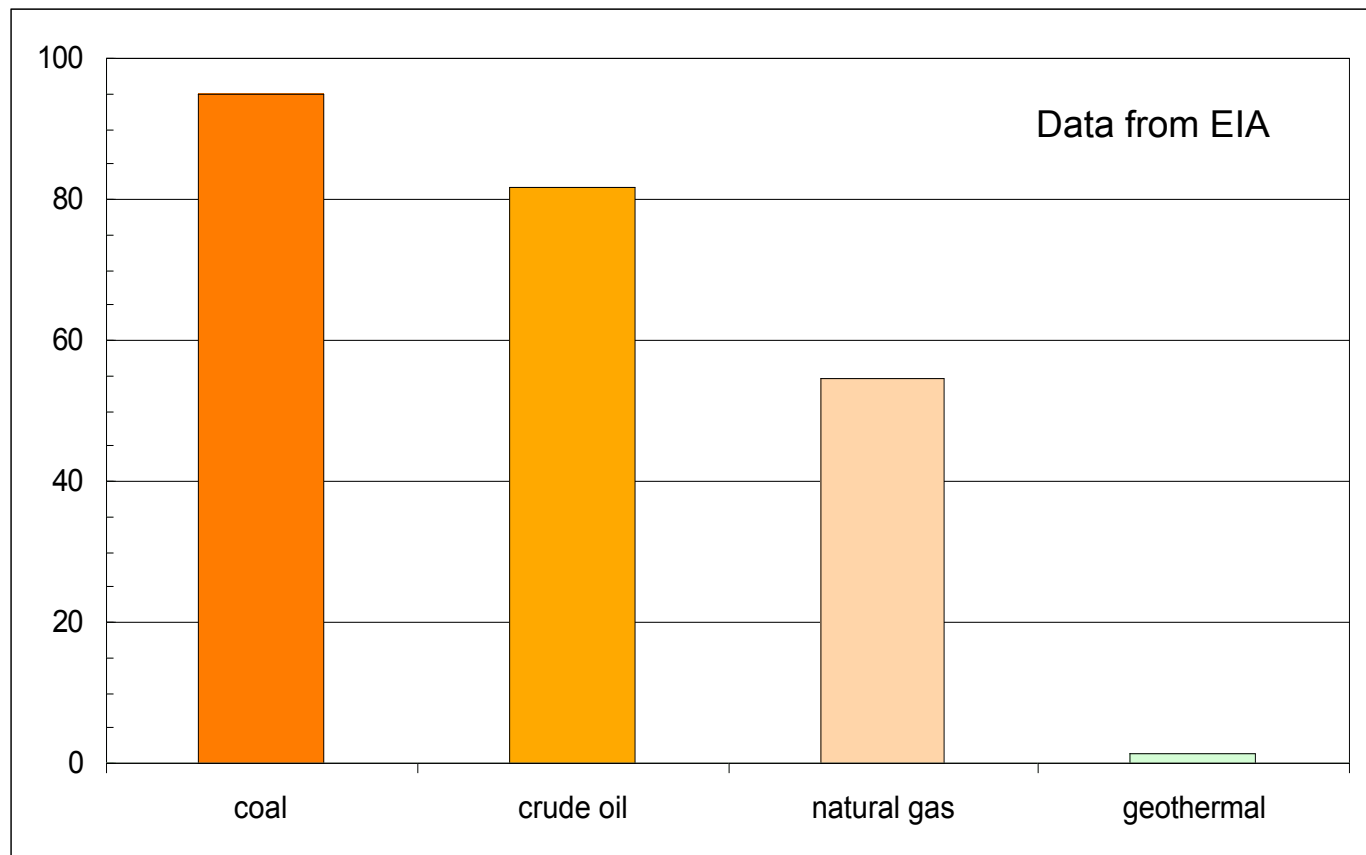


Hot water from oil wells at RMOTC (Johnson and Schochet, 2007)

Geothermal Energy – A Low-Carbon Energy Source

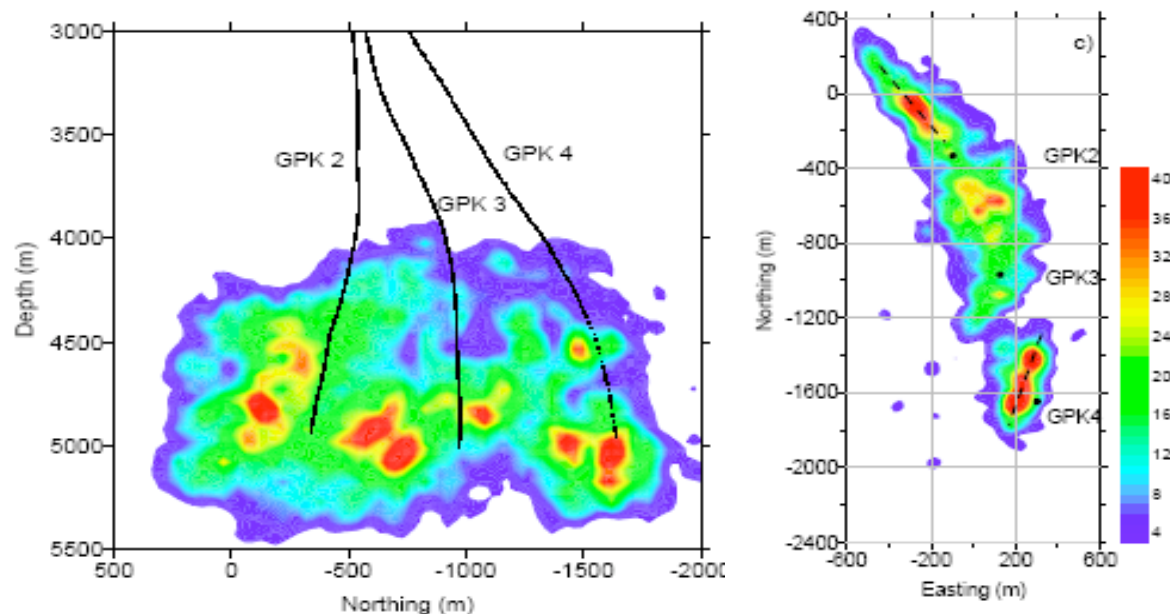
On an energy-equivalent basis, CO₂ emissions from geothermal use are significantly less than electricity generated using fossil fuels

Million Metric
Tons CO₂
Emitted per
Quad Energy
(Fuel)
Consumed for
Electric Power
Generation



Enhanced Geothermal Systems – Seismicity and Water

Maps of microearthquake density from reservoir stimulation



Soultz-sous-Forêts, France

- Stimulated Volume $\sim 6-8 \text{ km}^3$
- Temperature $\sim 200^\circ\text{C}$
- Potential Generation $\sim 1.5 \text{ MWe}$

(Tischner et al., 2007)

Geothermal Energy Development Needs

- **Incentives**
 - Federal
 - PTC/ Production Tax Credit
 - ITC/ Investment Tax Credit
 - Loan Guarantee
 - State
 - RPS/ Renewable Portfolio Standards
 - Tax Incentives

Geothermal Energy Development Needs

- DOE Support
 - R&D on New Technology
 - Exploration drilling and conversion technology
 - Cost Share Programs
 - Exploration and drilling
 - Integrated Transmission Studies
 - Addresses Federal, State and Local issues
 - Addressing private, tribal and sensitive lands
 - Involves all renewables
 - Outreach and Education

Summary

- The USGS has completed an assessment of our Nation's geothermal resources in fulfillment of the mandate from the Energy Policy Act of 2005.
- The mean electric power generation potential from **Identified Geothermal Systems** is **9,057 MWe**, distributed over 13 states.
- The mean estimated power production potential from **Undiscovered Geothermal Resources** is **30,033 MWe**.
- Another estimated **517,800 MWe** could be generated through the implementation of **Enhanced Geothermal Systems (EGS)** technology for creating geothermal reservoirs in regions characterized by high temperature, but low permeability, rock formations.
- Future assessment work will address unconventional geothermal resources in greater detail, including the availability of water for resource utilization.

Geothermal Strategic Value

- **Clean** electricity generation
- **Baseload** power production, high capacity factors
- **Distributed** energy systems with **modular** and shorter development timeframe advantages.
- **Direct-use** building energy needs
- **Ethanol & biodiesel** production (thermal energy requirements)
- **Hydrogen** production (via off-peak electrolysis)
- **Enhanced oil recovery** gaining more oil plus electric power
- **Climate change** mitigation
- **Rural economic development** (e.g., aquaculture and horticulture, timber/lumber drying)
- **Mineral recovery** (e.g., silica and zinc – plus other strategic minerals in short supply)



Acknowledgements:

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