



# The USGS National Geothermal Resource Assessment

Colin F. Williams, USGS, Menlo Park, CA  
Brenda S. Pierce, USGS, Reston, VA

<http://energy.usgs.gov/other/geothermal/>

# Outline

- **The Energy Issue**
- Background on Geothermal Energy
- USGS National Resource Assessment Project
- Assessment Results
  - Identified Geothermal Systems
  - Undiscovered Geothermal Resources
  - Enhanced Geothermal Systems
- Future Assessment Work
- Summary

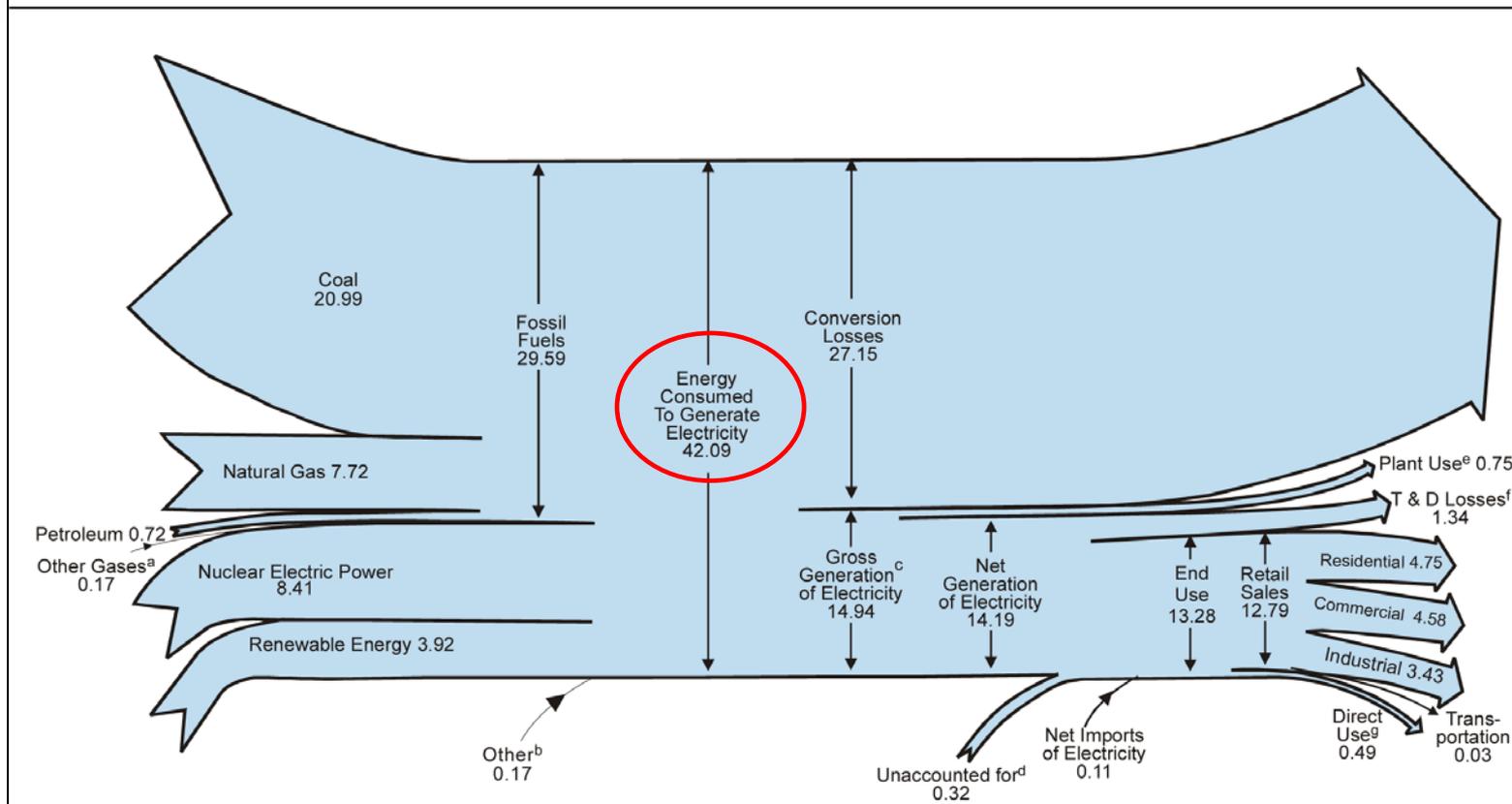
# The Energy Issue

*The United States needs energy supplies that are secure, uninterrupted, sustainable, and economically and environmentally viable. Based on current projections, **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).*

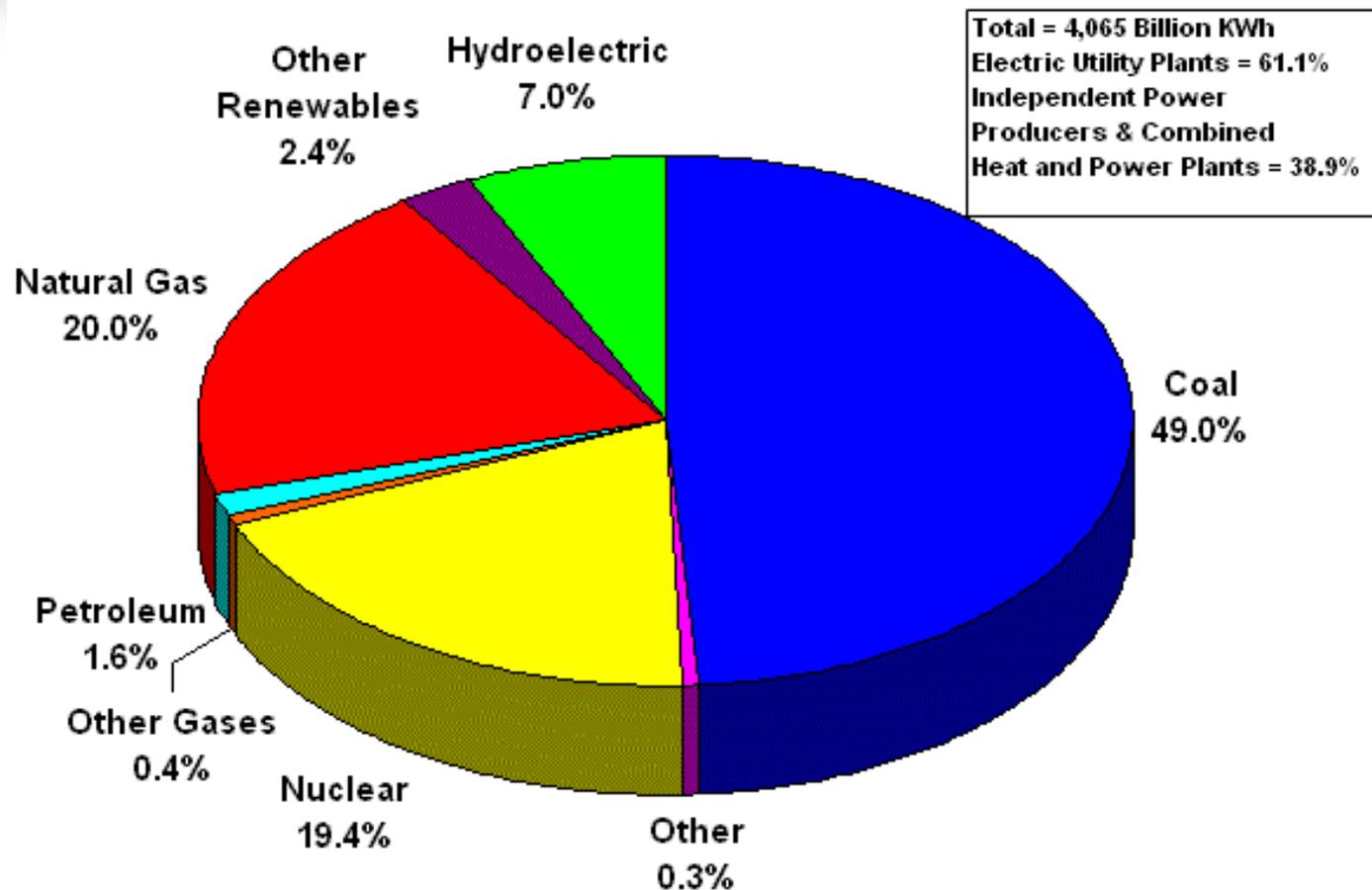
*Geothermal energy constitutes one of the United States' largest sources of renewable energy. A critical question for the near future is the extent to which geothermal resources can help meet the increasing demand for electricity.*

# U.S. Electric Power Generation Mix

**Diagram 5. Electricity Flow, 2007**  
(Quadrillion Btu)



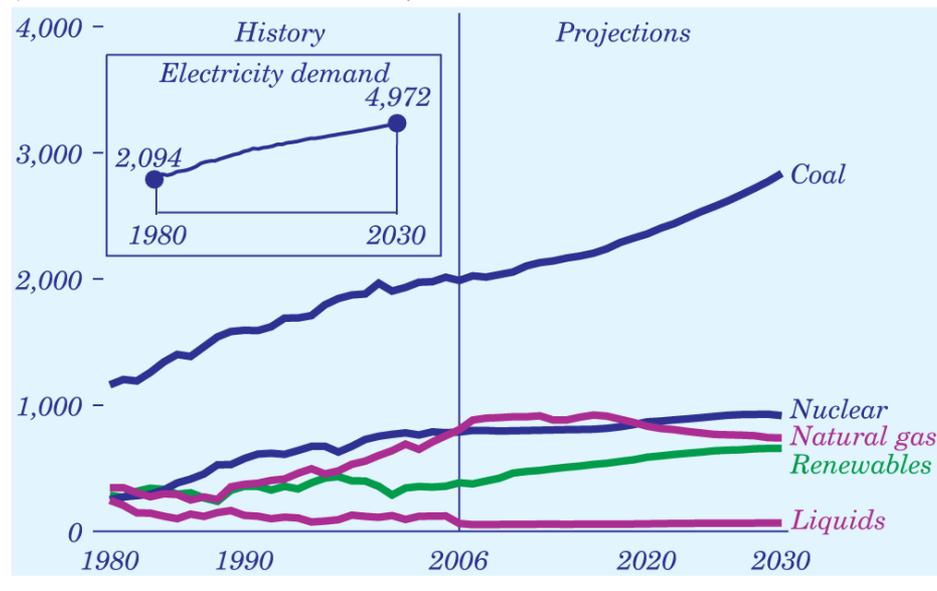
# U.S. Electric Power Generation Mix - 2



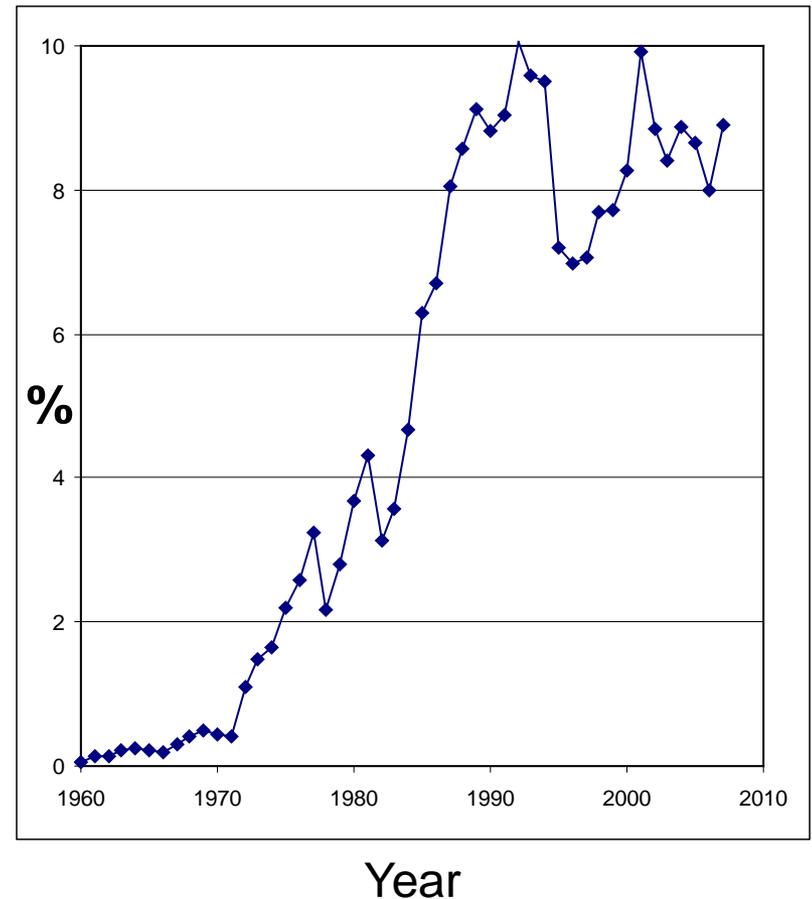
# Geothermal and Future U.S. Electric Power Generation

Can geothermal help meet future electric power demands?

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

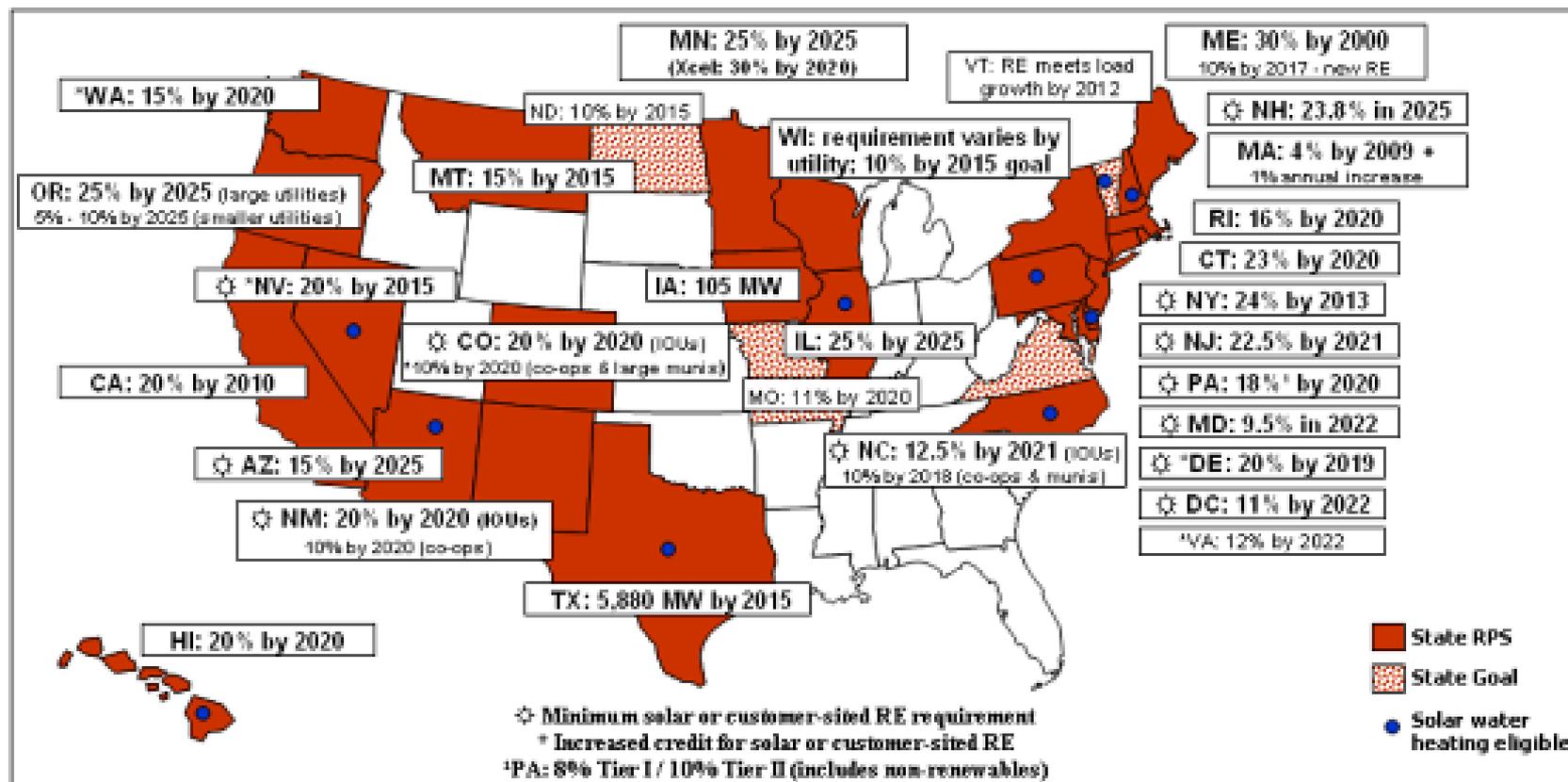


Percentage Renewable Energy Consumption by the Electric Power Generation Sector derived from Geothermal Resources



# Renewable Portfolio Standards

Figure 1.11. Renewables Portfolio Standards

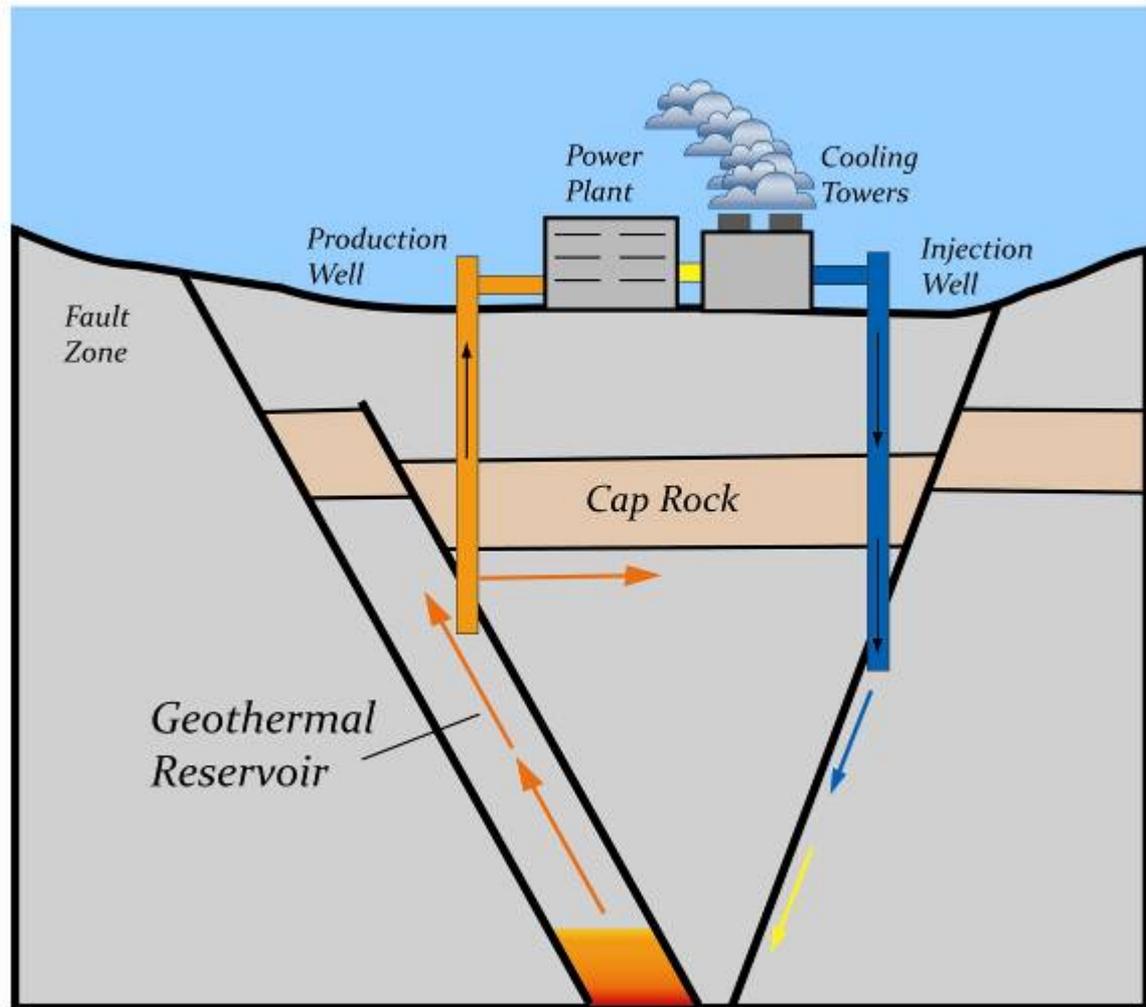


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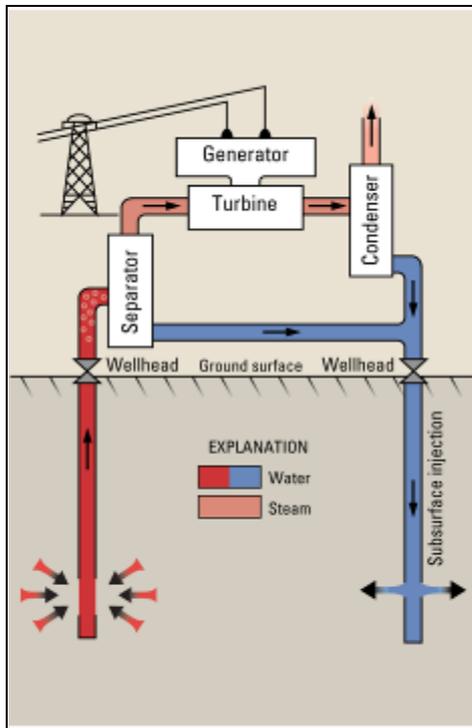
# Idealized Geothermal Power Plant

Need: Heat  
(Temperature)  
and Fluid  
(Permeability)

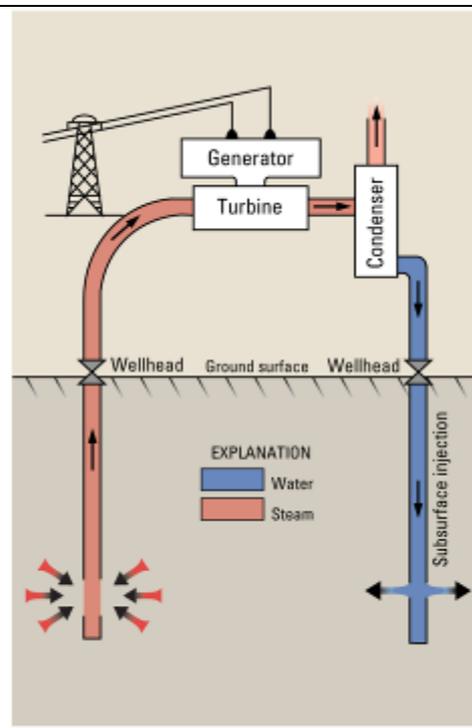


# Electricity Generation from Geothermal Energy

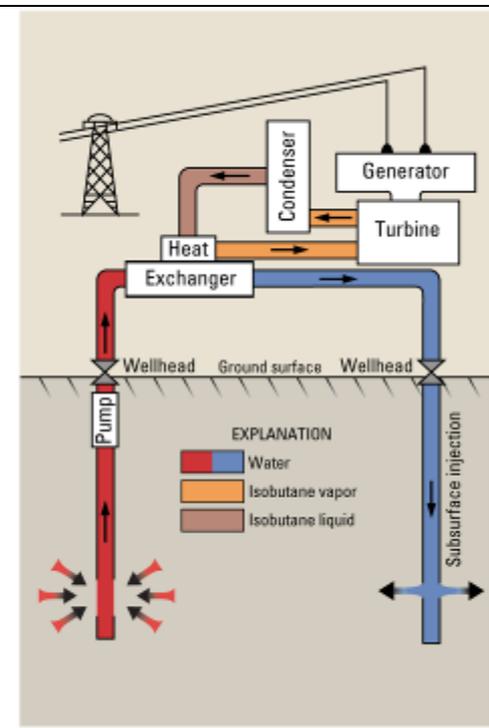
## Hot water flash



## Steam



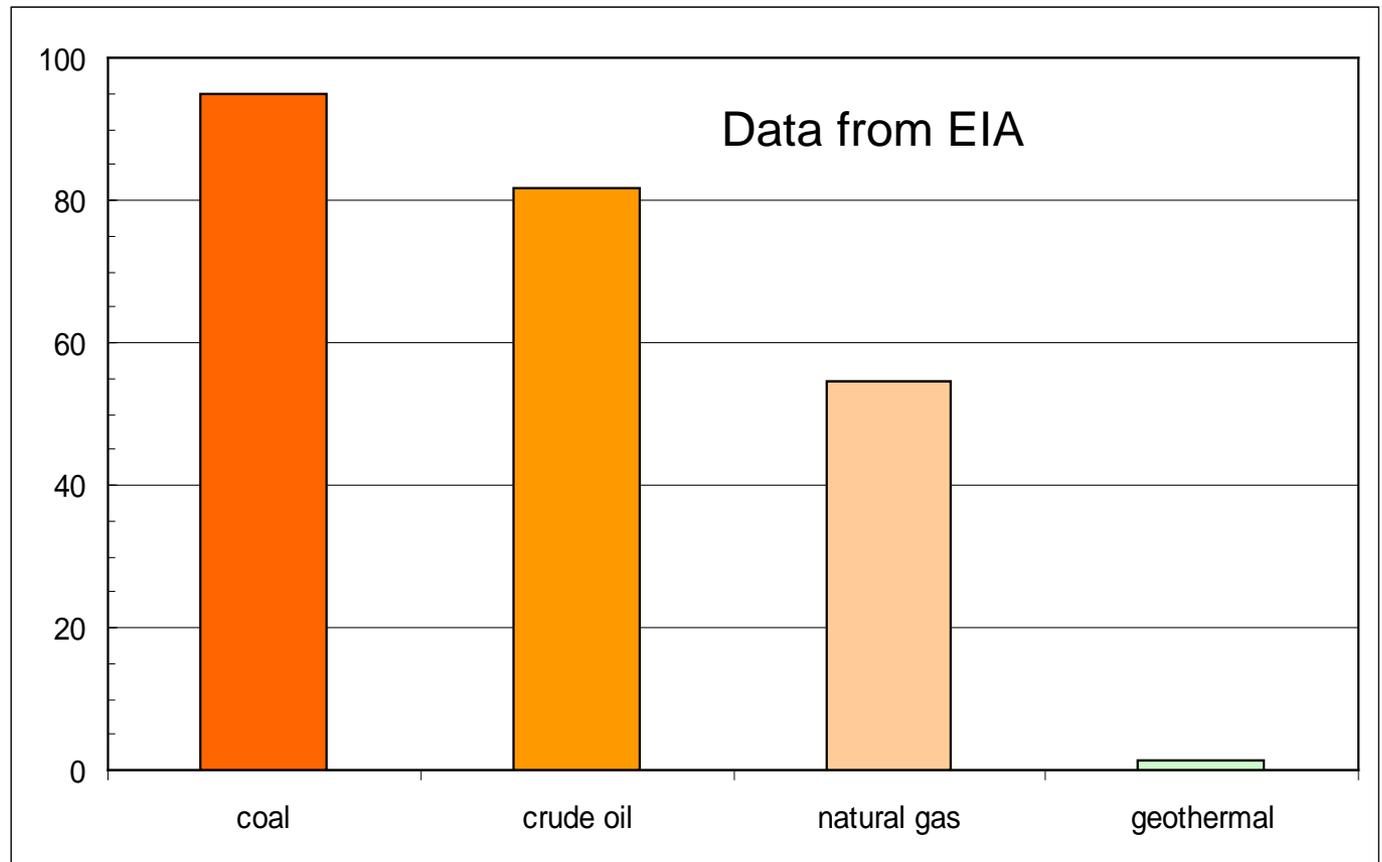
## Binary



# Geothermal Energy – A Low-Carbon Fuel

On an energy-equivalent basis, CO<sub>2</sub> emissions from geothermal use are significantly less than electricity generated using fossil fuels

Million Metric  
Tons CO<sub>2</sub>  
Emitted per  
Quad Energy  
(Fuel)  
Consumed for  
Electric Power  
Generation



# Status of Geothermal Energy

- More than **2500 Megawatts-electric (MWe)** installed Geothermal generation capacity
  - **~15,000 Gigawatt-hours (GWh)** of Geothermal power in 2005
- Expected growth in US electric power requirements
  - **300,000 MWe** in 20 years
- 1978 USGS Geothermal Resource Assessment (USGS Circular 790)
  - **23,000 MWe** in identified systems
  - **~100,000 MWe** in undiscovered systems
- How do 30 years of research and development alter resource estimates?
- To what degree does limited development reflect limited resources, economics, technology and land use issues?

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# USGS National Geothermal Resource Assessment

- Mandated in Energy Policy Act of 2005
- 3-year Effort Funded in FY2006
- DOE Support for Cooperative Projects in FY2005-8
- Collaborators - DOE, BLM, US Navy, USFS, Universities, State and Local Agencies, Industry.
- The resource assessment includes estimates of electric power production potential from
  - Identified Geothermal Systems
  - Undiscovered Geothermal Resources
  - *Enhanced/Engineered Geothermal Systems*

# USGS 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 – Scientific and Technological Developments

## USGS Circular 790

Temperature  $>150^{\circ}\text{C}$  and Depth  $<3$  km for electric power production

52 identified high temperature systems

Identified systems poorly characterized

Idealized reservoir performance

Rough estimates of undiscovered resources

EGS mentioned but not estimated



## New USGS assessment

Temperature  $>90^{\circ}\text{C}$  and Depth up to 6 km for electric power production ( $\sim 75^{\circ}\text{C}$  in Alaska)

241 identified moderate and high temperature systems

Abundant exploration and production data

Improved models for reservoir performance

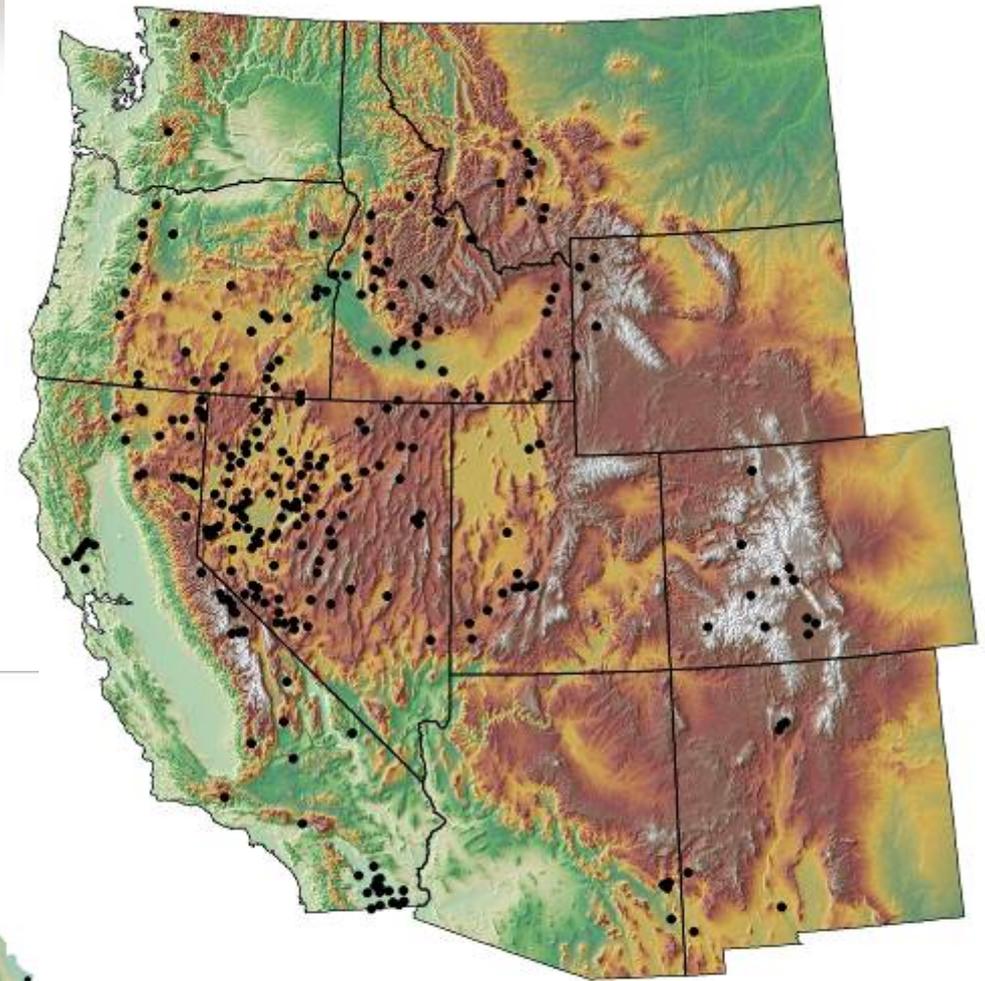
Better quantitative estimates of undiscovered resources

Enhanced Geothermal Systems included

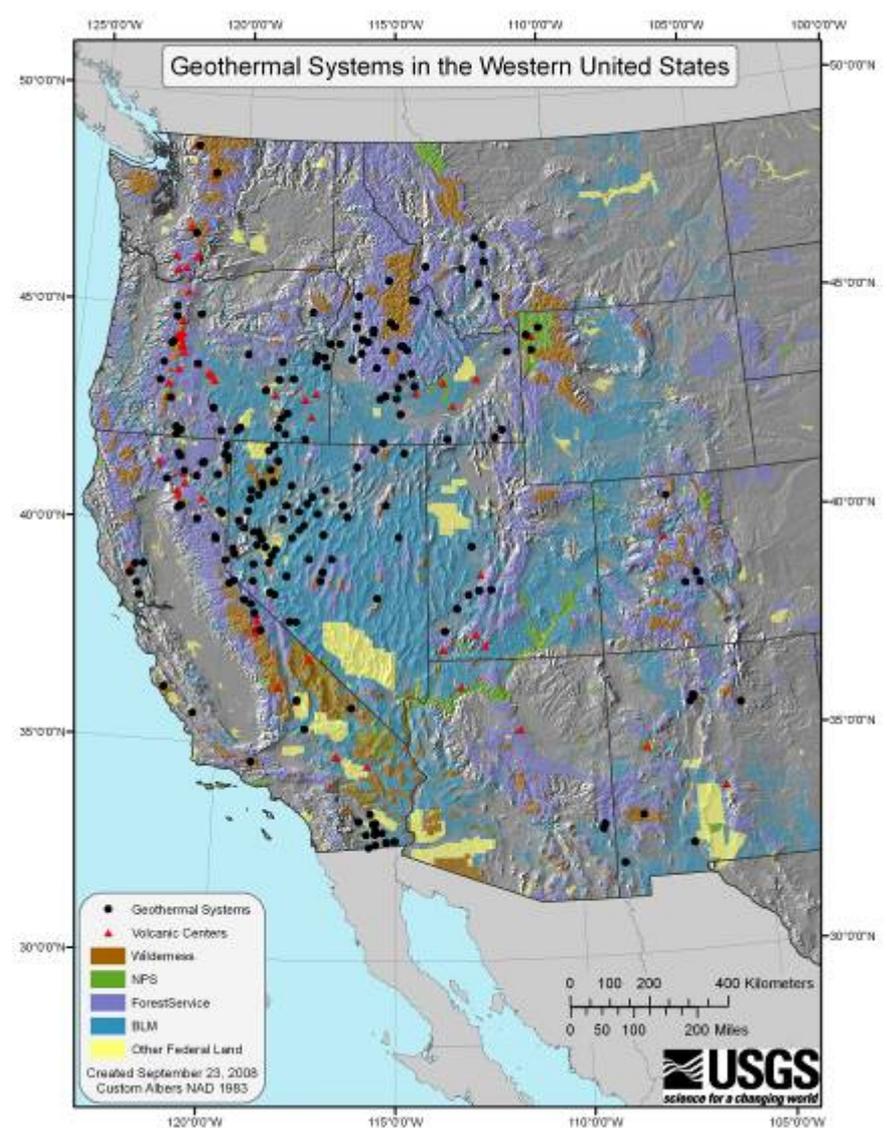
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# Identified Geothermal Systems

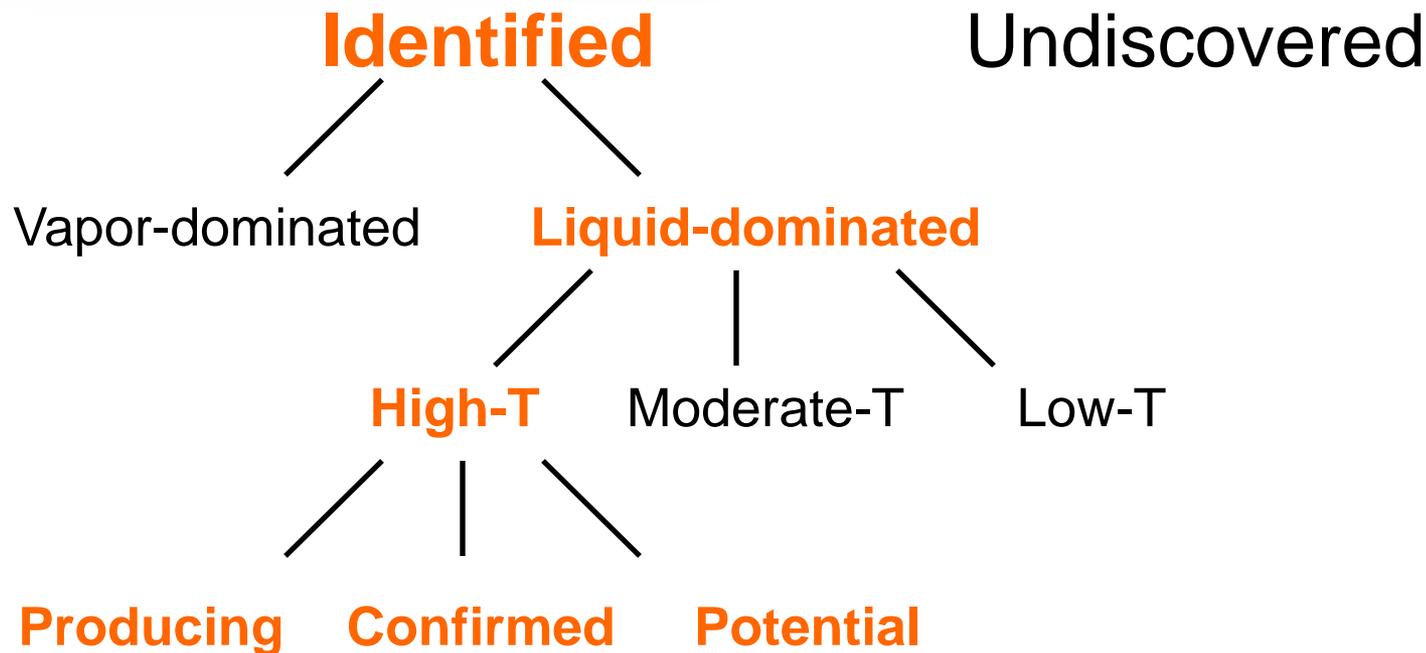


# Geothermal Systems and Public Lands





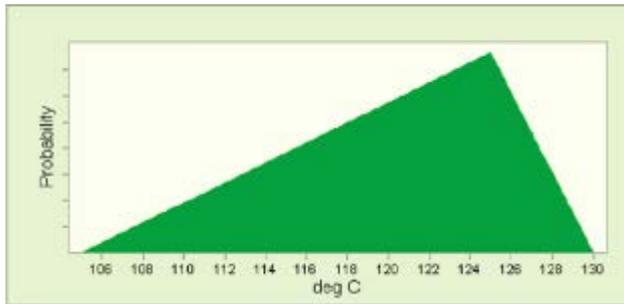
# Geothermal Resource Categories



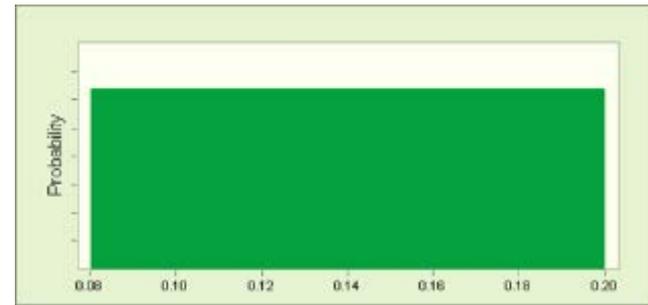
Only terms highlighted in **orange** show complete categories. Others follow similar subdivisions (e.g., high, moderate or low temperature). By definition, undiscovered resources cannot be subdivided into producing, confirmed or potential.

# Monte Carlo Simulation of Geothermal Resources

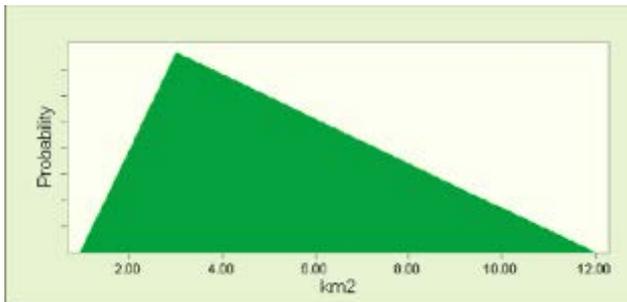
## Reservoir Temperature



## Recovery Factor

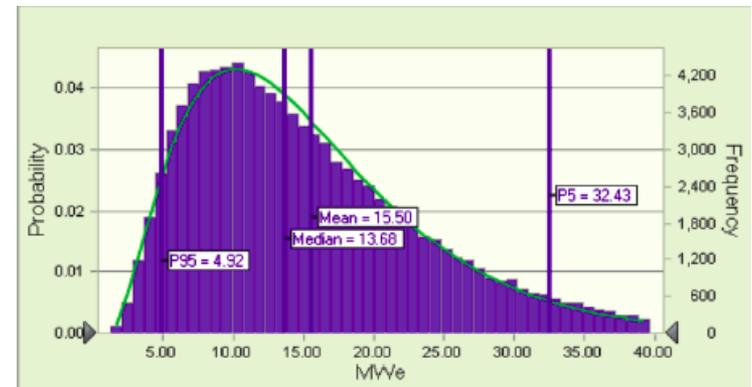


## Reservoir Volume

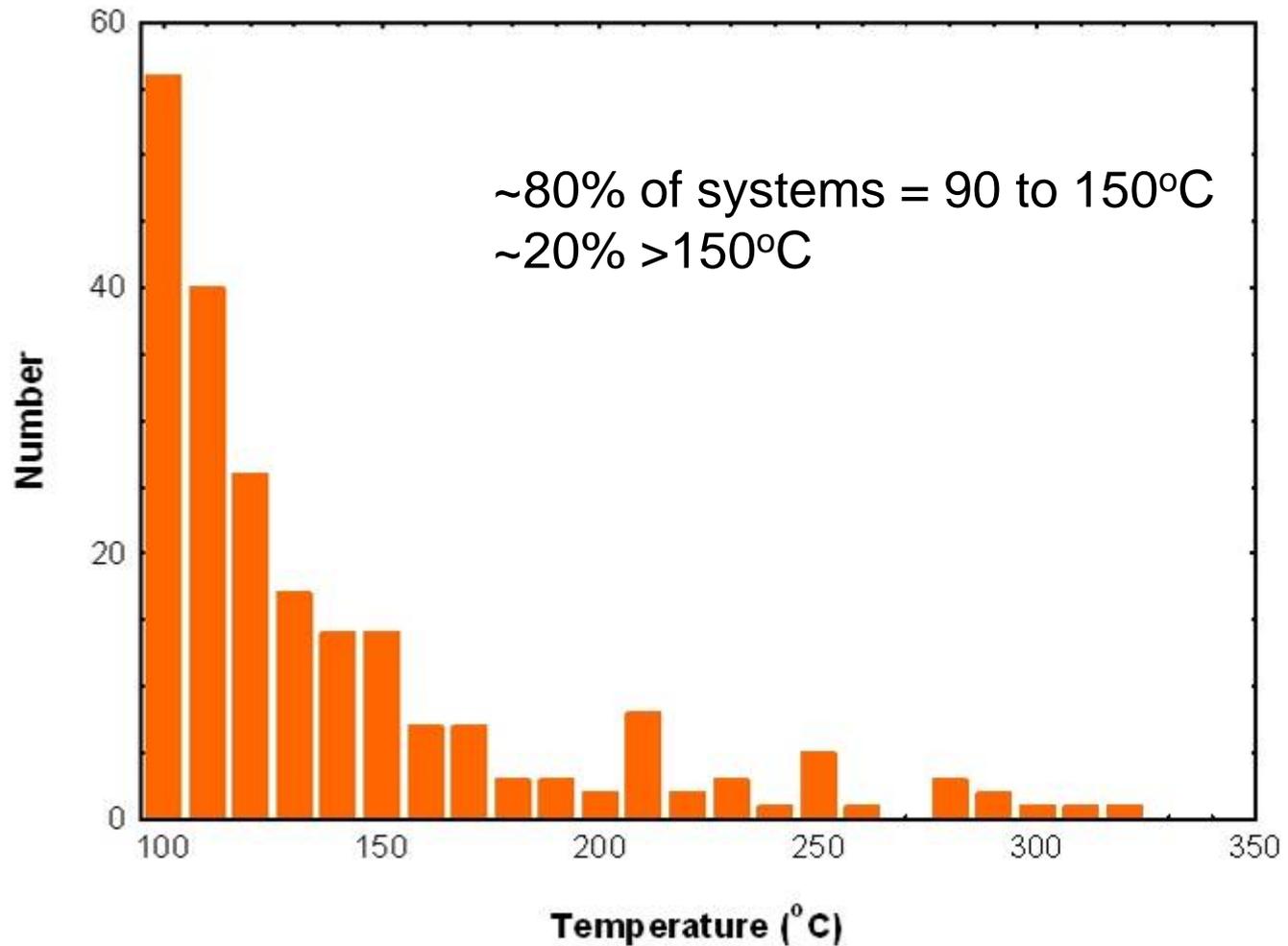


Reservoir  
Thermal  
Energy

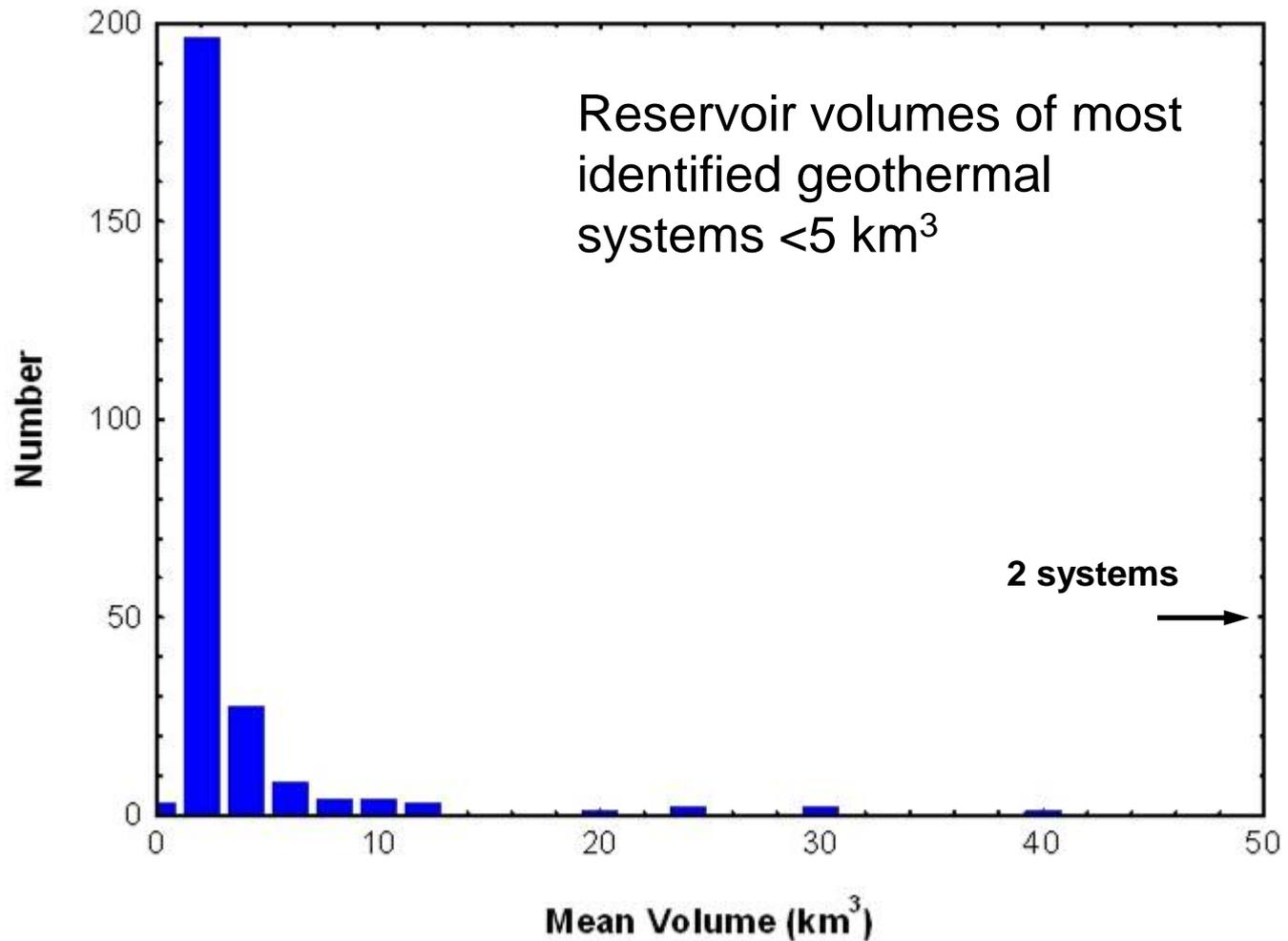
## Electric Power



# Temperature Distribution of Identified Systems



# Volume Distribution of Identified Systems



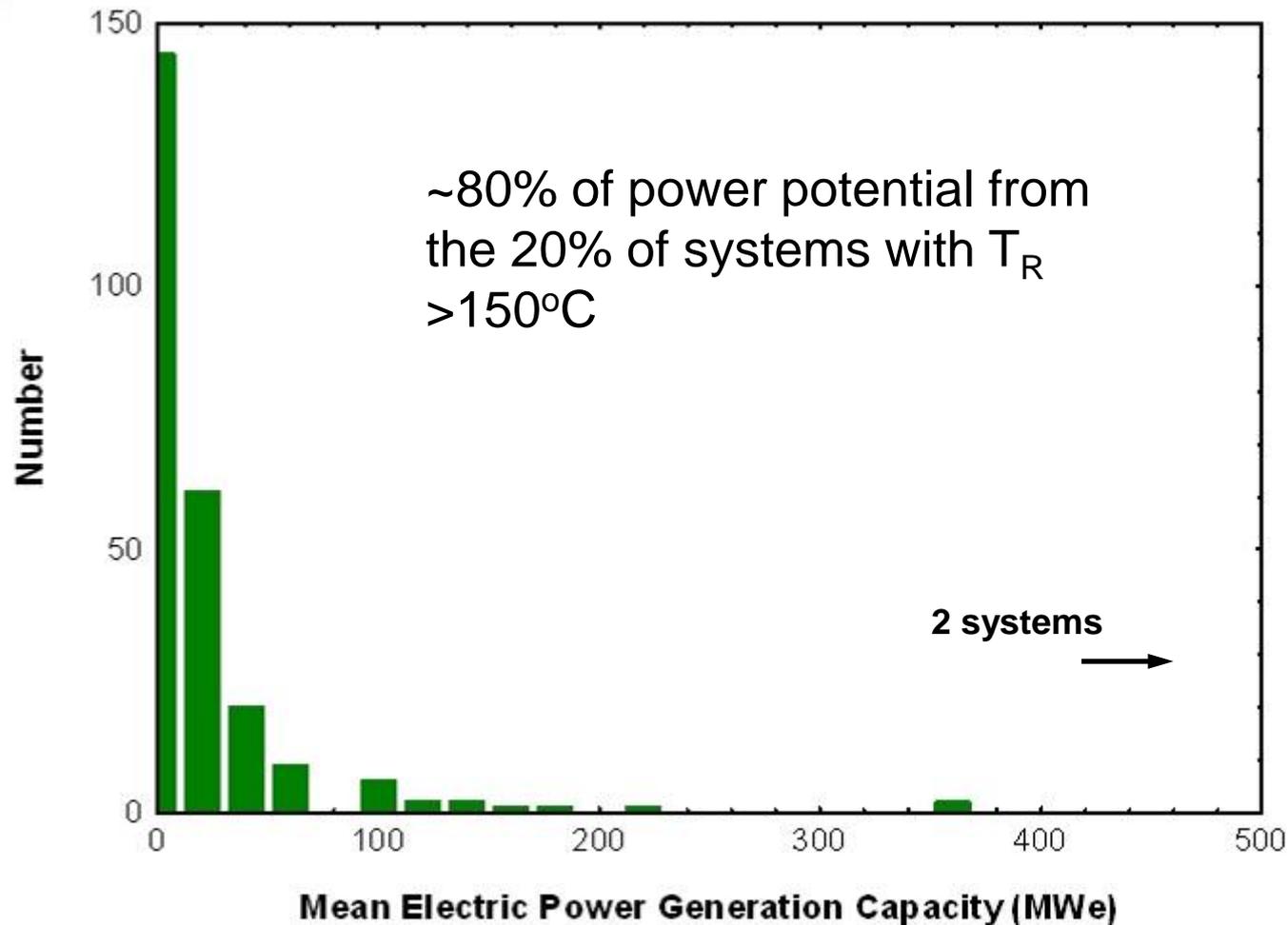
# Power Distribution of Identified Systems

Identified Systems  
Potential –

Mean = 9057 MWe

F95 = 3675 MWe

F5 = 16457 MWe

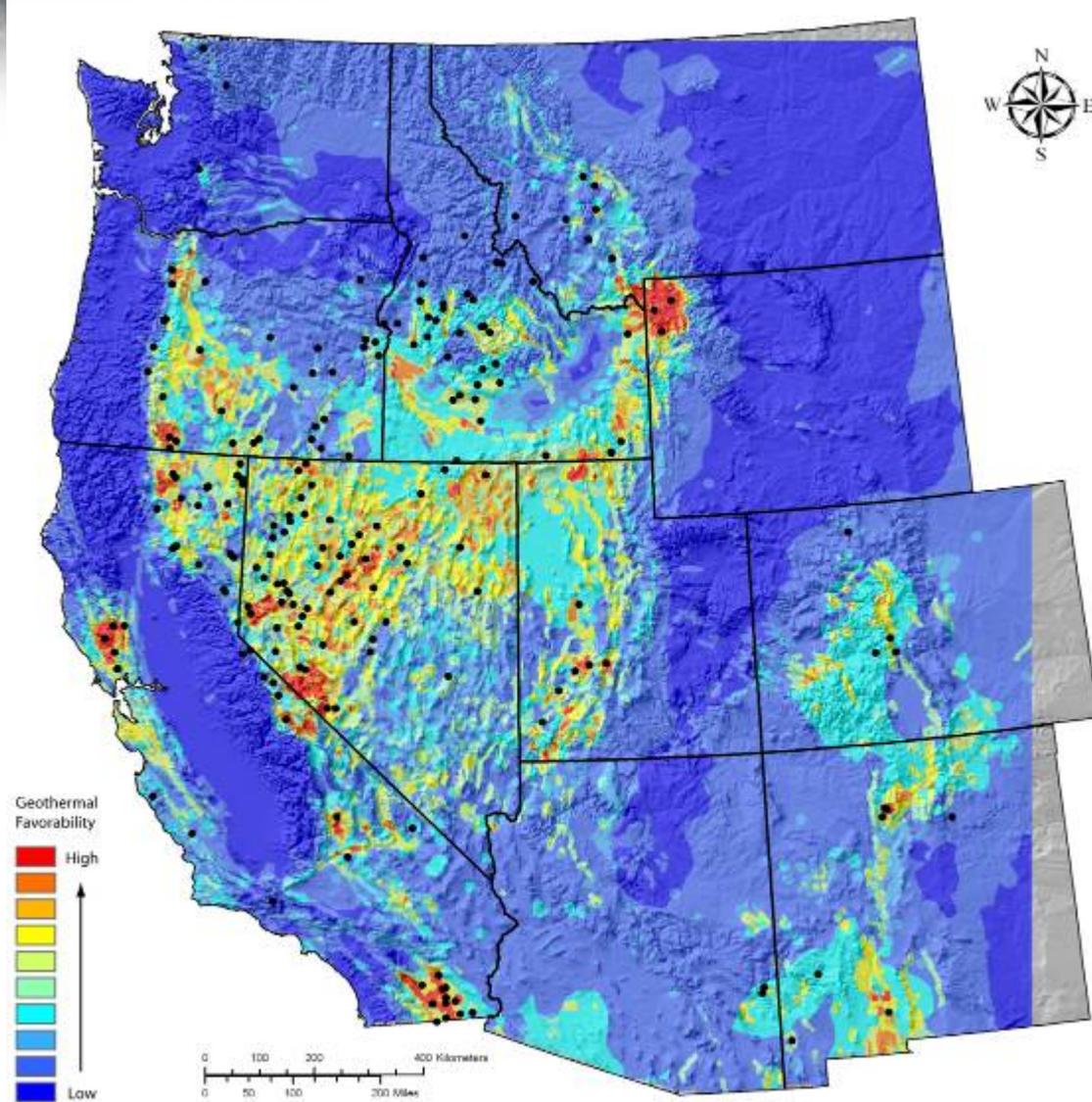


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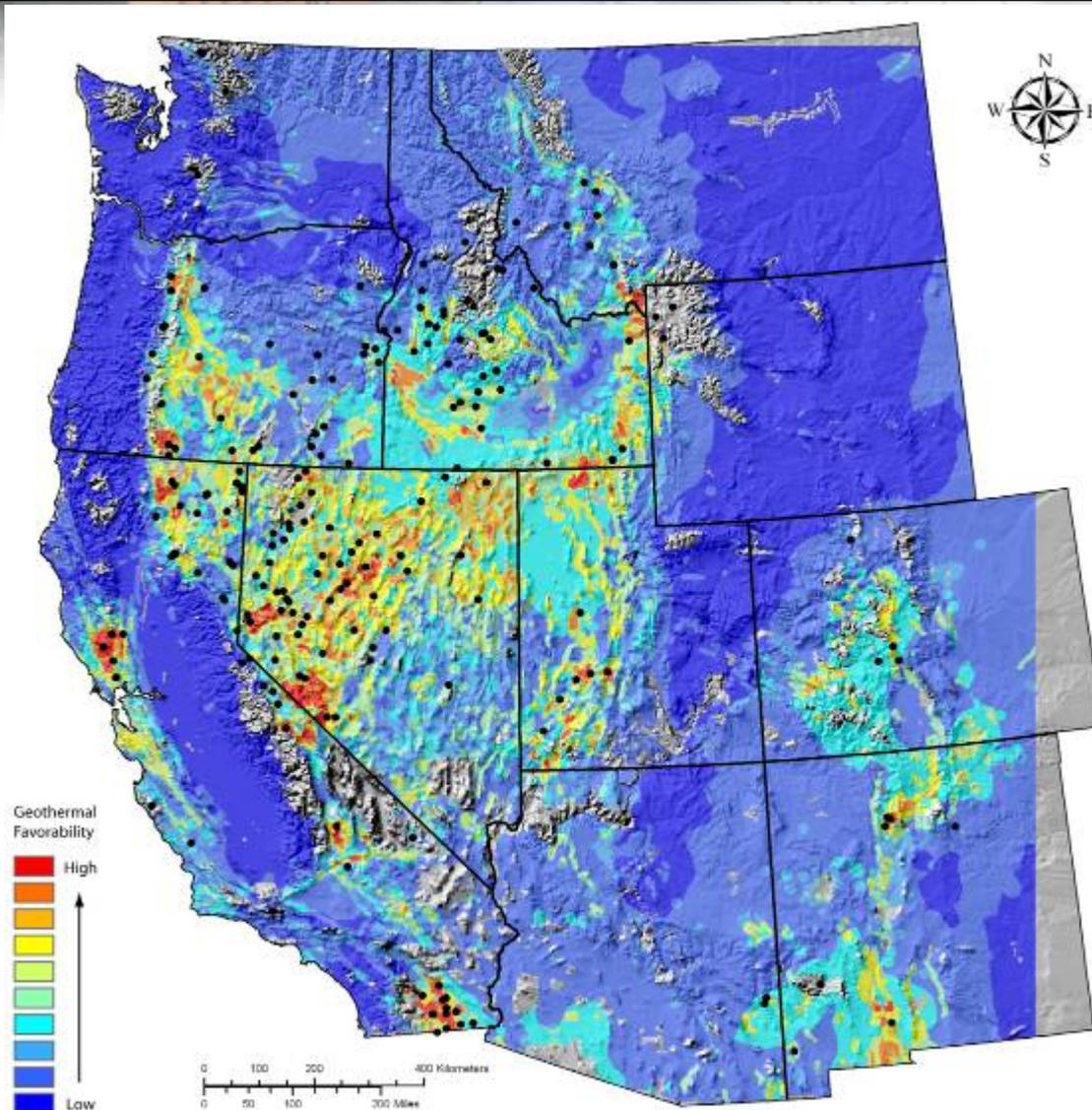
# Undiscovered Resources – Geothermal Favorability Maps

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

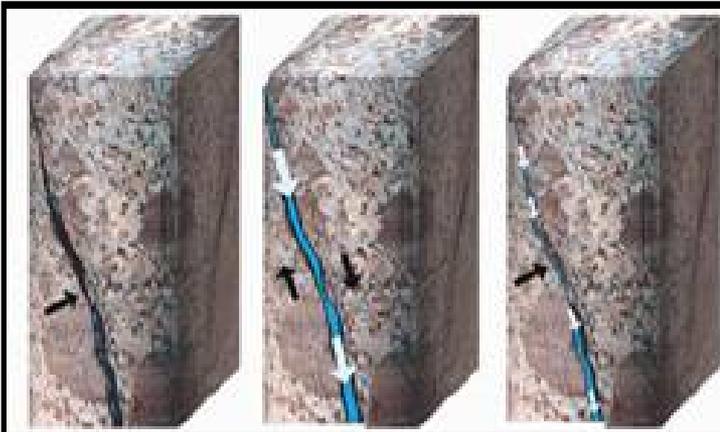
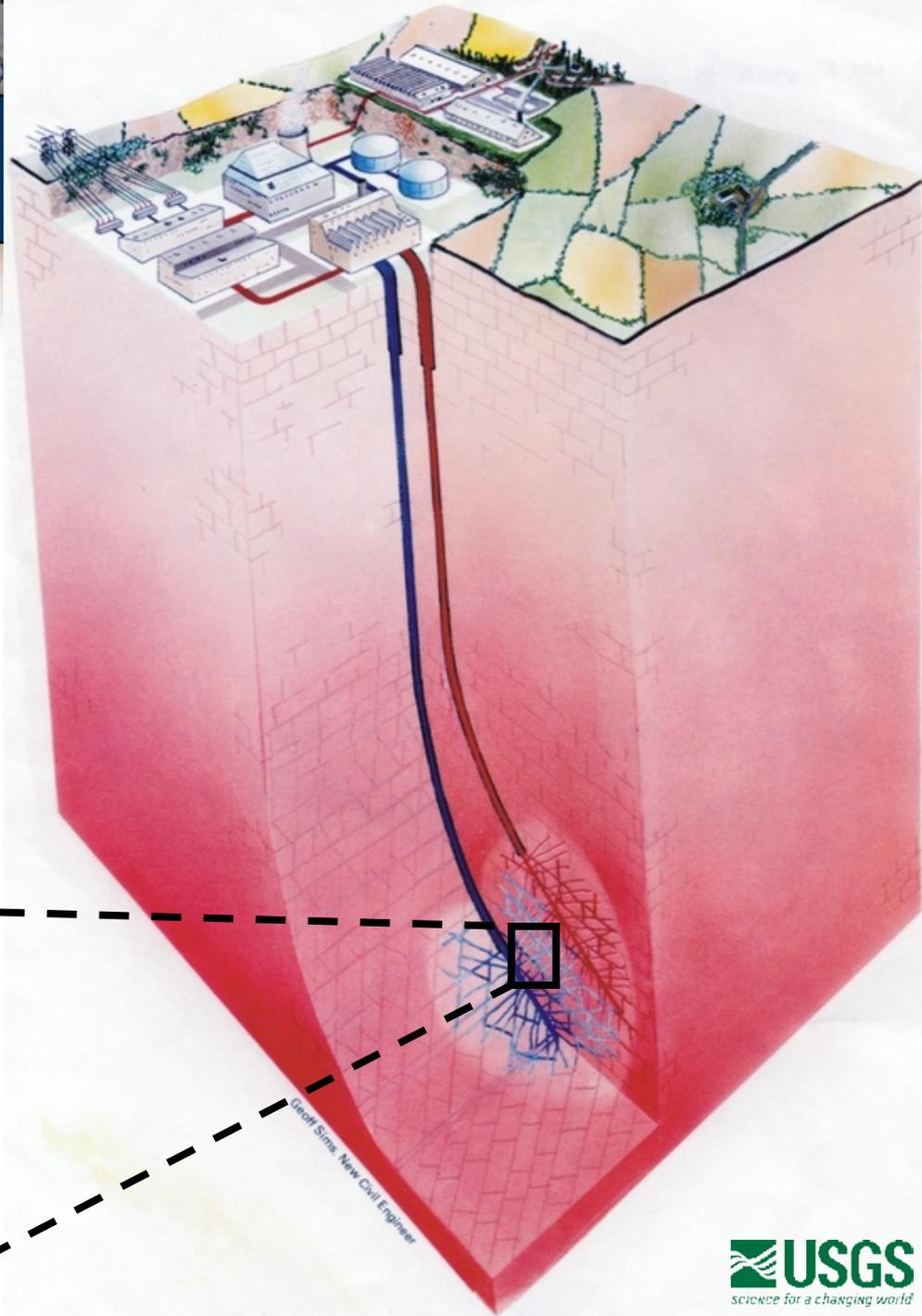


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# Enhanced Geothermal Systems (EGS)

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



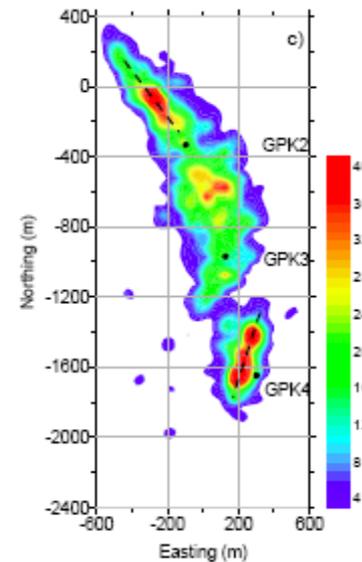
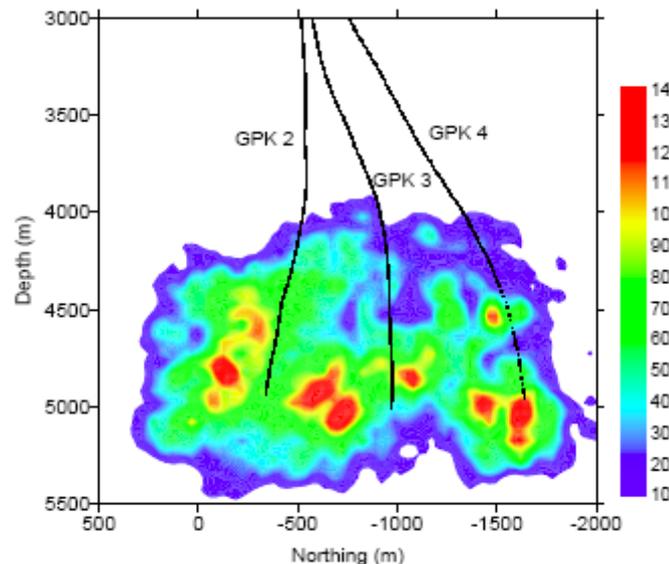
Geoff Sims, New Civil Engineer

A map of the western United States, showing the Pacific Northwest, California, and Nevada. A red line with arrows indicates a path or boundary across the region, likely representing a geothermal resource distribution or project area.

# 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



Maps of  
microearthquake  
density from  
reservoir  
stimulation

Soutz-sous-Forets, France

Stimulated Volume  $\sim 6-8 \text{ km}^3$

Temperature  $\sim 200^\circ\text{C}$

Potential Generation  $\sim 1.5 \text{ MWe}$

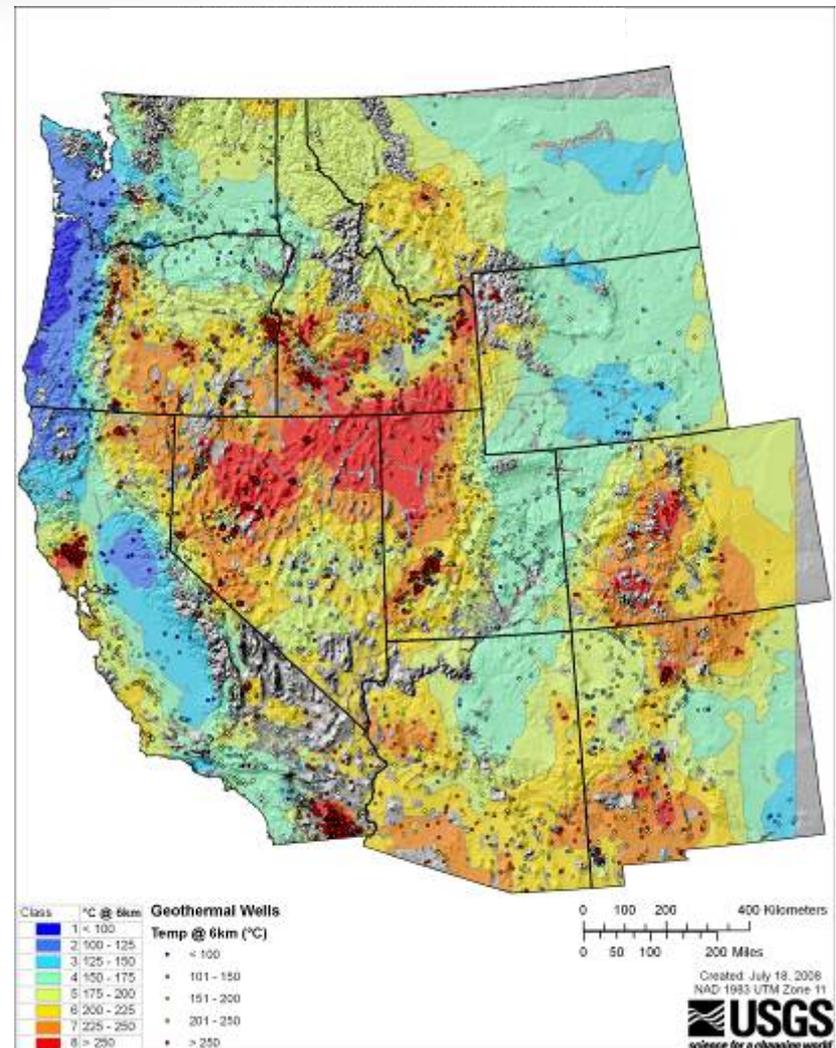
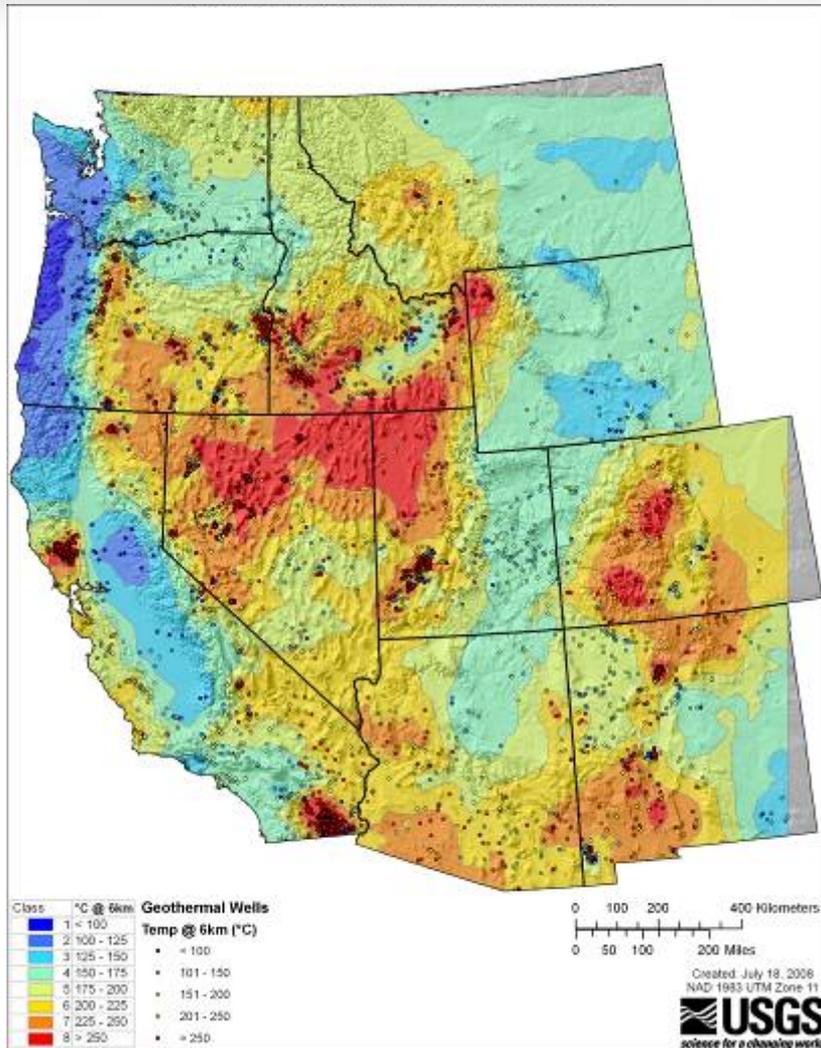
(Tischner et al., 2007)



# Enhanced Geothermal Systems – USGS Deep Temperatures

Temperature contours

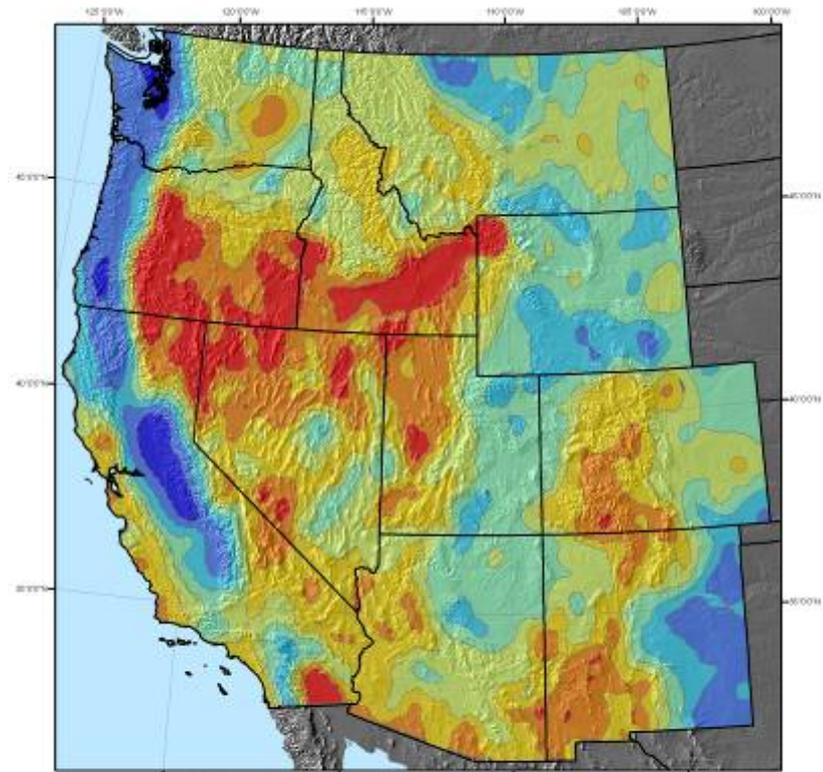
Temperature contours w/o closed public lands



# Enhanced Geothermal Systems – SMU Deep Temperatures

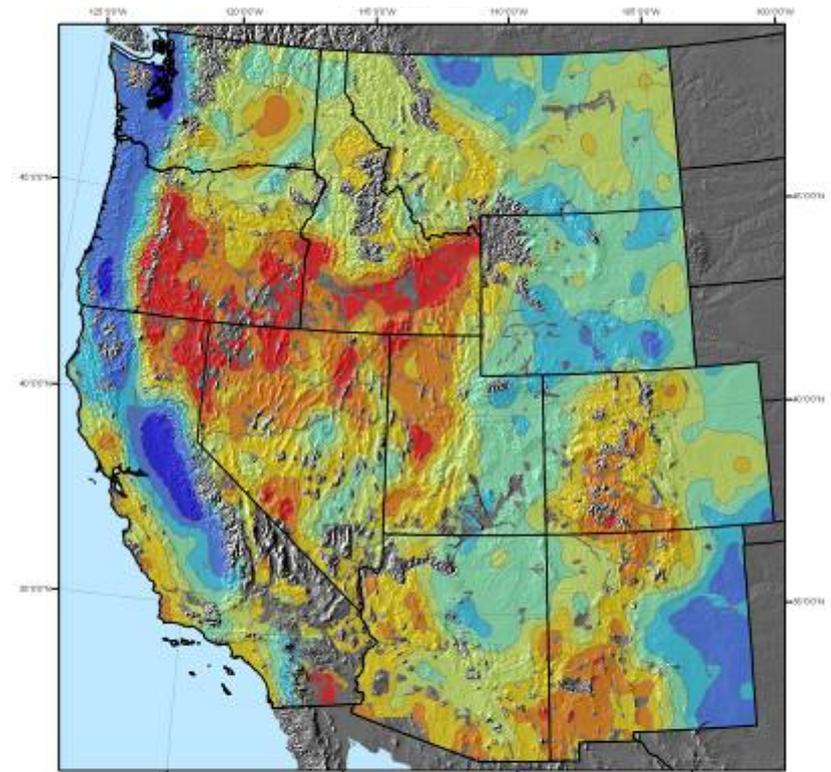
Temperature contours

Temperature contours w/o closed public lands



Class	Temp (°C)
1	75 - 100
2	100 - 125
3	125 - 150
4	150 - 175
5	175 - 200
6	200 - 225
7	225 - 250
8	>250

Created July 18, 2008  
UTM Zone 12 NAD1983  
**USGS**  
science for a changing world



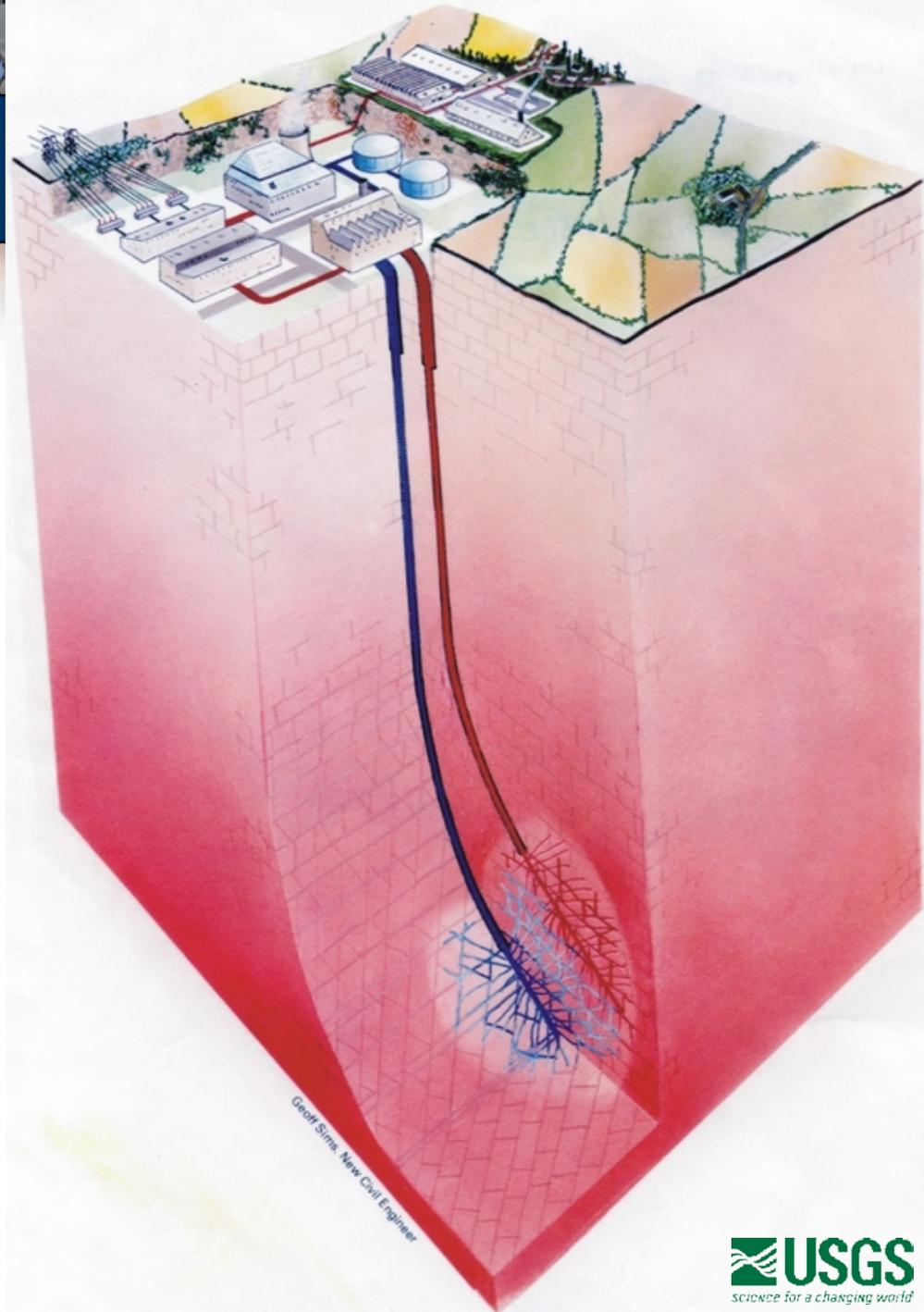
Class	Temp (°C)
1	75 - 100
2	100 - 125
3	125 - 150
4	150 - 175
5	175 - 200
6	200 - 225
7	225 - 250
8	>250

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# Enhanced Geothermal Systems (EGS)

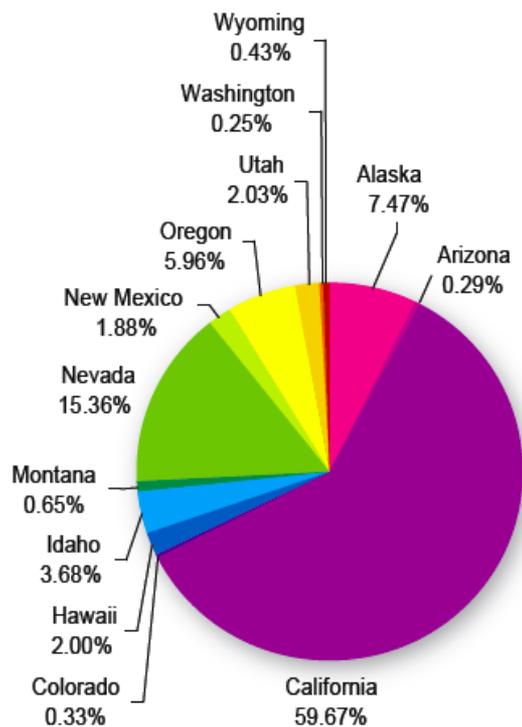
EGS Resources –  
Mean = 517,800 MWe  
F95 = 345,100 MWe  
F5 = 727,900 MWe

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

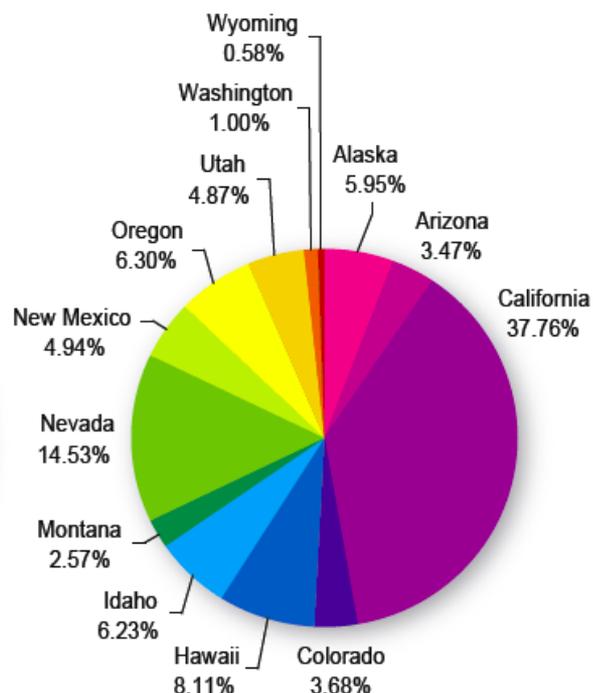


# Distribution of Geothermal Potential

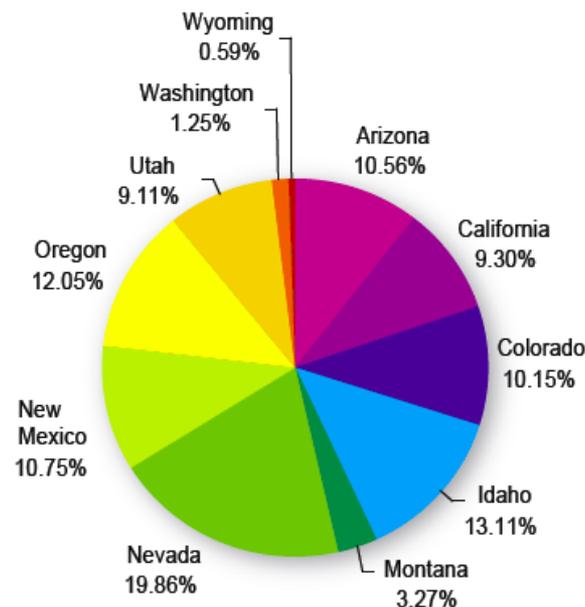
A. Identified Geothermal Resources



B. Undiscovered Resources



C. Enhanced Geothermal Systems



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# Directions for Future Work

- Publish Supporting Reports and Databases
- Update Assessment Results
- Improved Enhanced Geothermal Systems Assessment Methodology
- Assess Other Unconventional Geothermal Resources
  - Geopressured Geothermal
  - Co-produced Geothermal with Oil&Gas

# Summary

- 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 potential from **Identified Geothermal Systems** alone 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.

# Acknowledgements

## **USGS Energy Resources Program**

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## **USGS Geothermal Resource Studies Project and colleagues**

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**Thank You**



<http://energy.usgs.gov/>