



The USGS National Geothermal Resource Assessment

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

U.S. Department of the Interior
U.S. Geological Survey



Outline

- Energy Issues (Greater Needs – Global Warming)
- Background on Geothermal Energy
- USGS National Resource Assessment Project
- Assessment Results
 - Identified Geothermal Systems
 - Undiscovered Geothermal Resources
 - Enhanced Geothermal Systems
- Summary

A background map of the Pacific Northwest region, showing the coastline of Washington and Oregon, with the name 'JUAN DE FUCA' visible in the water.

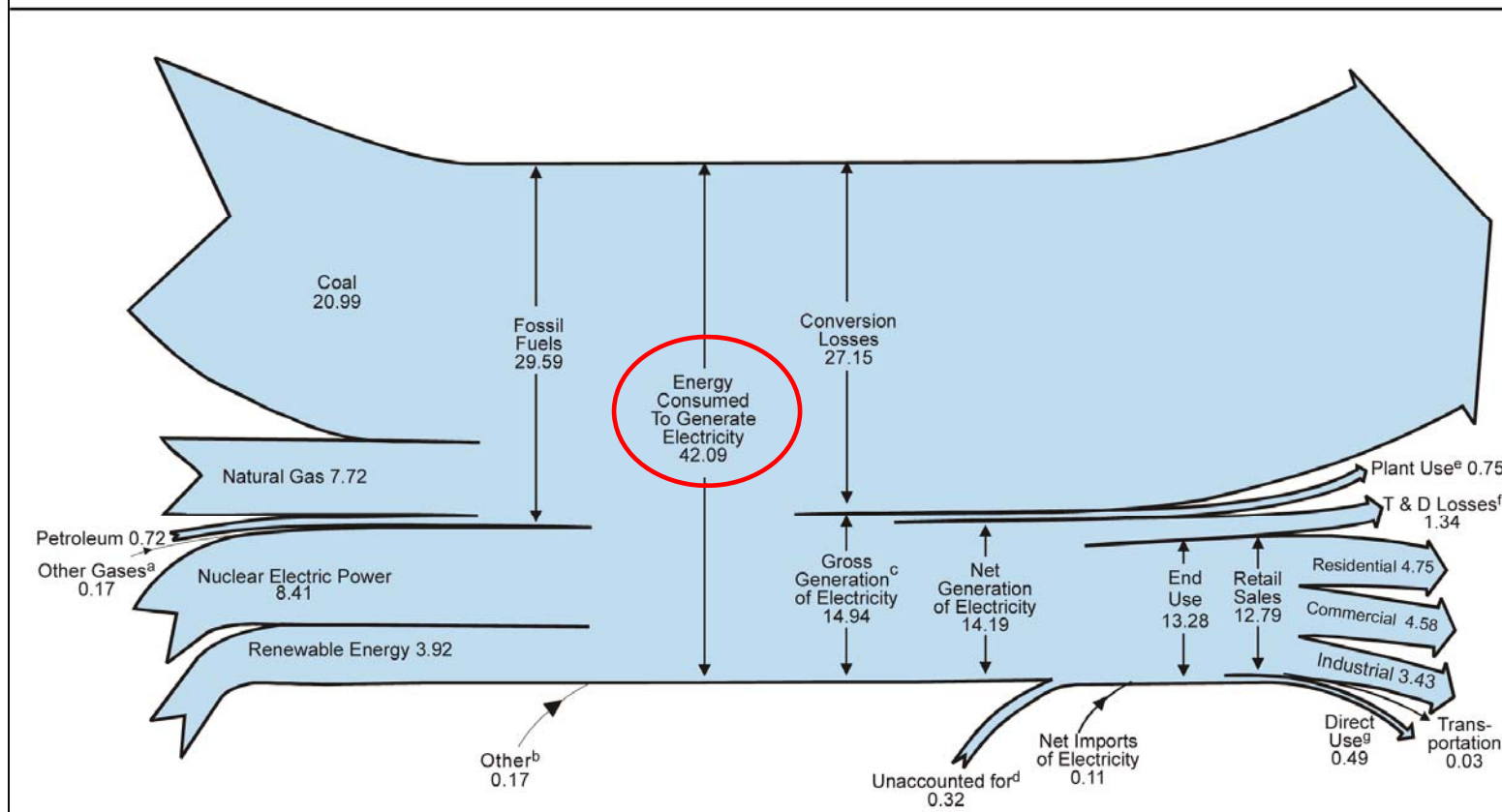
Energy Issues (Greater Need)

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.

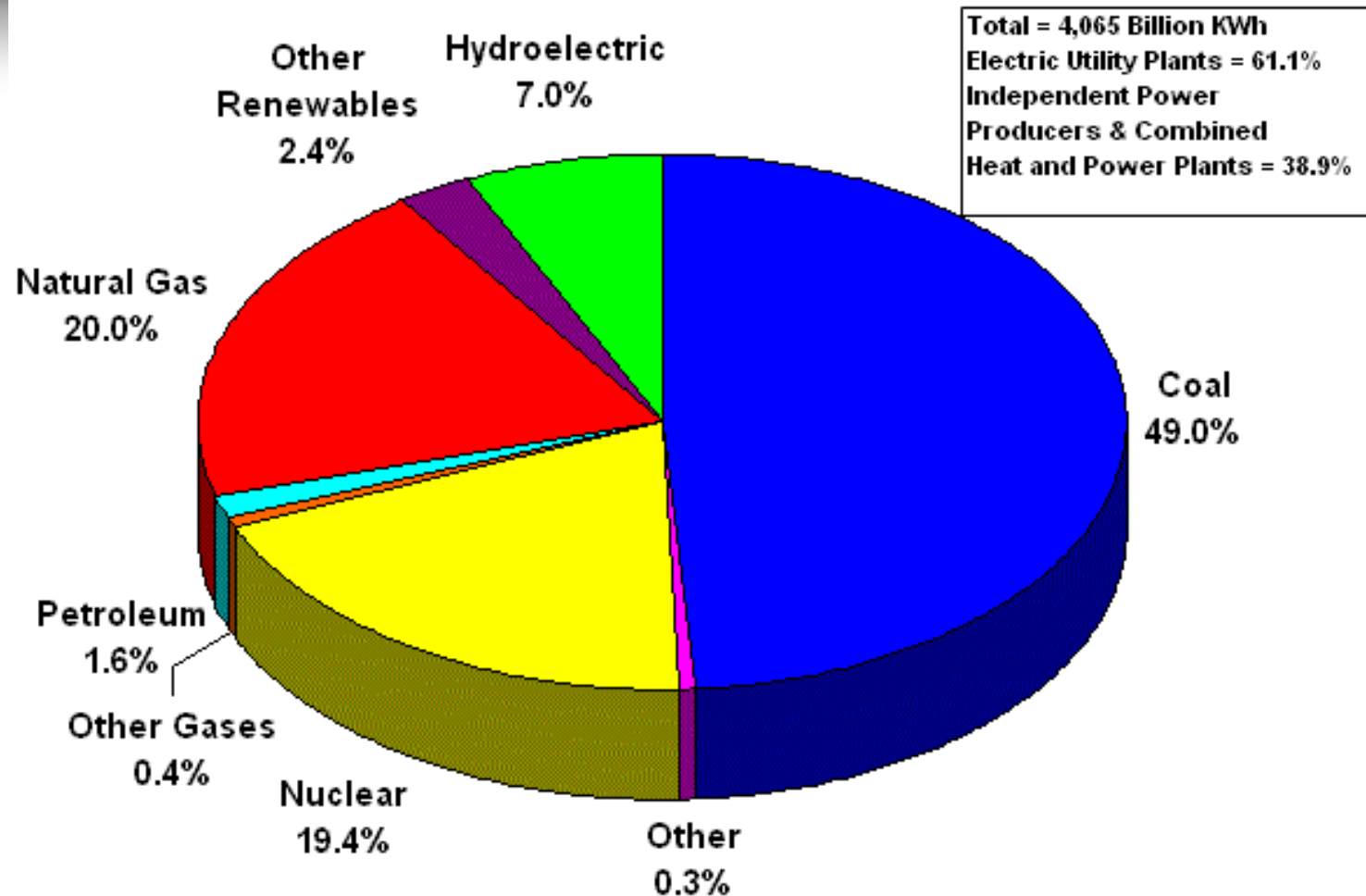
(Energy Information Administration).

U.S. Electric Power Generation Mix

Diagram 5. Electricity Flow, 2007
(Quadrillion Btu)



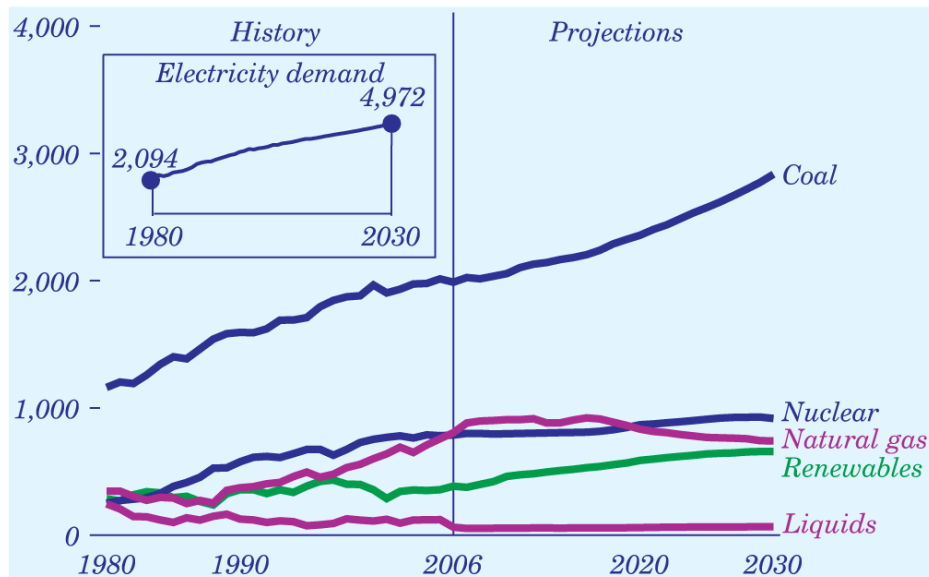
U.S. Electric Power Generation Mix - 2



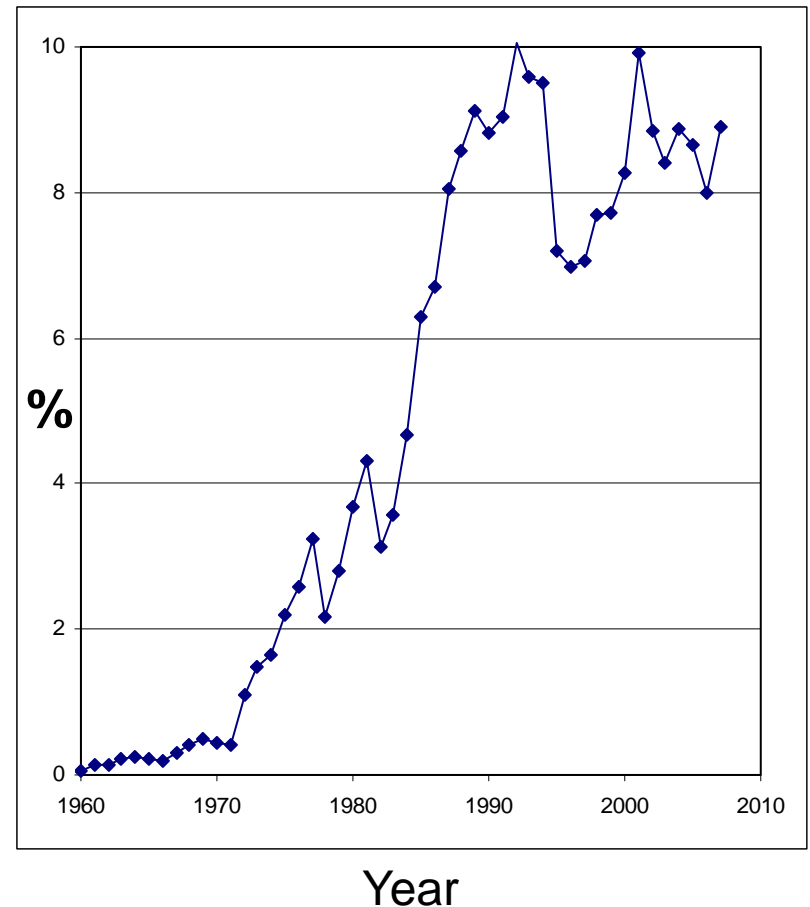
Geothermal and Future U.S. Electric Power Generation

Can geothermal help meet future electric power demands?

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

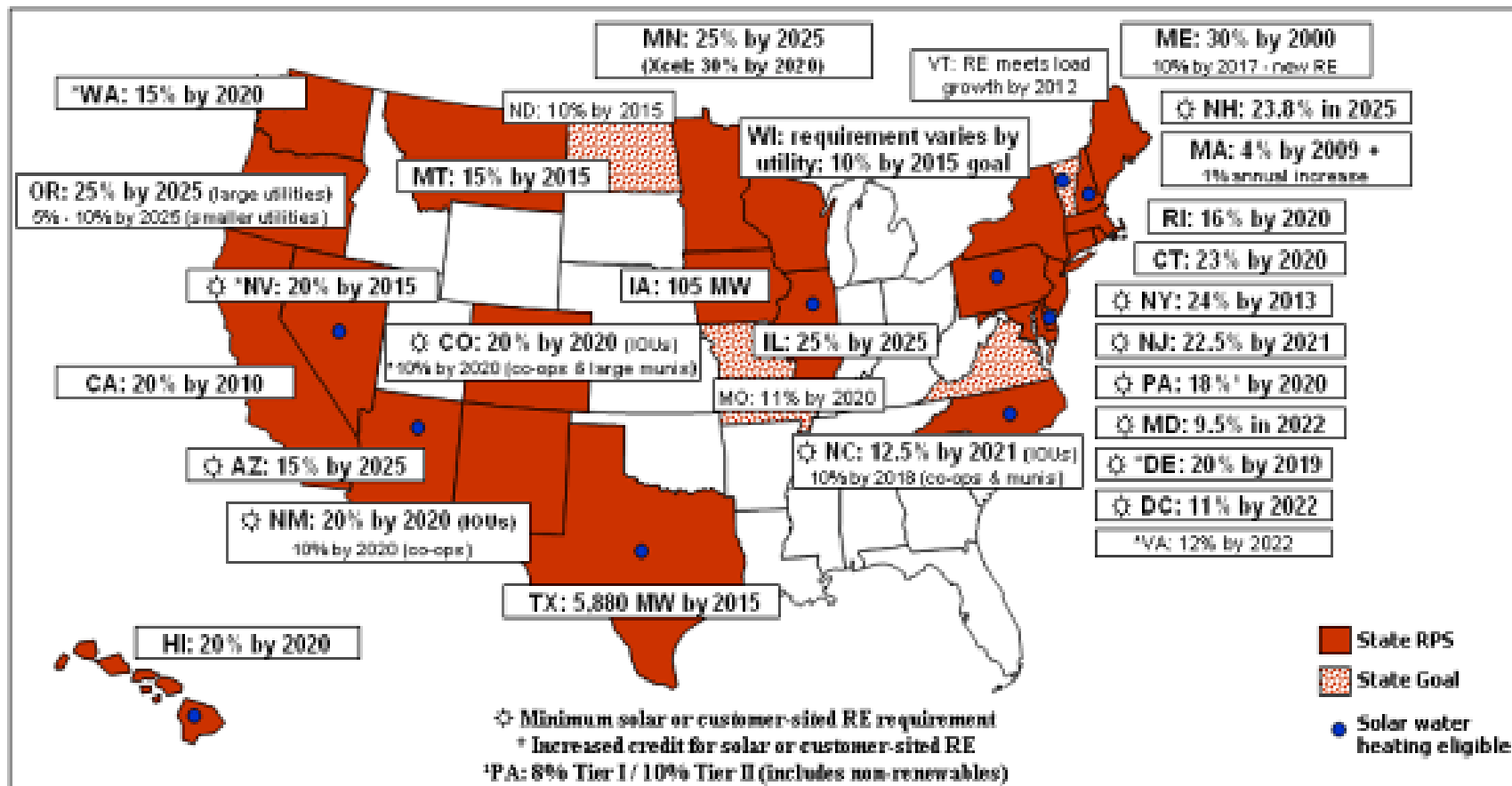


Percentage Renewable Energy Consumption by the Electric Power Generation Sector derived from Geothermal Resources



Energy Issues (Global Warming)

Renewable Portfolio Standards

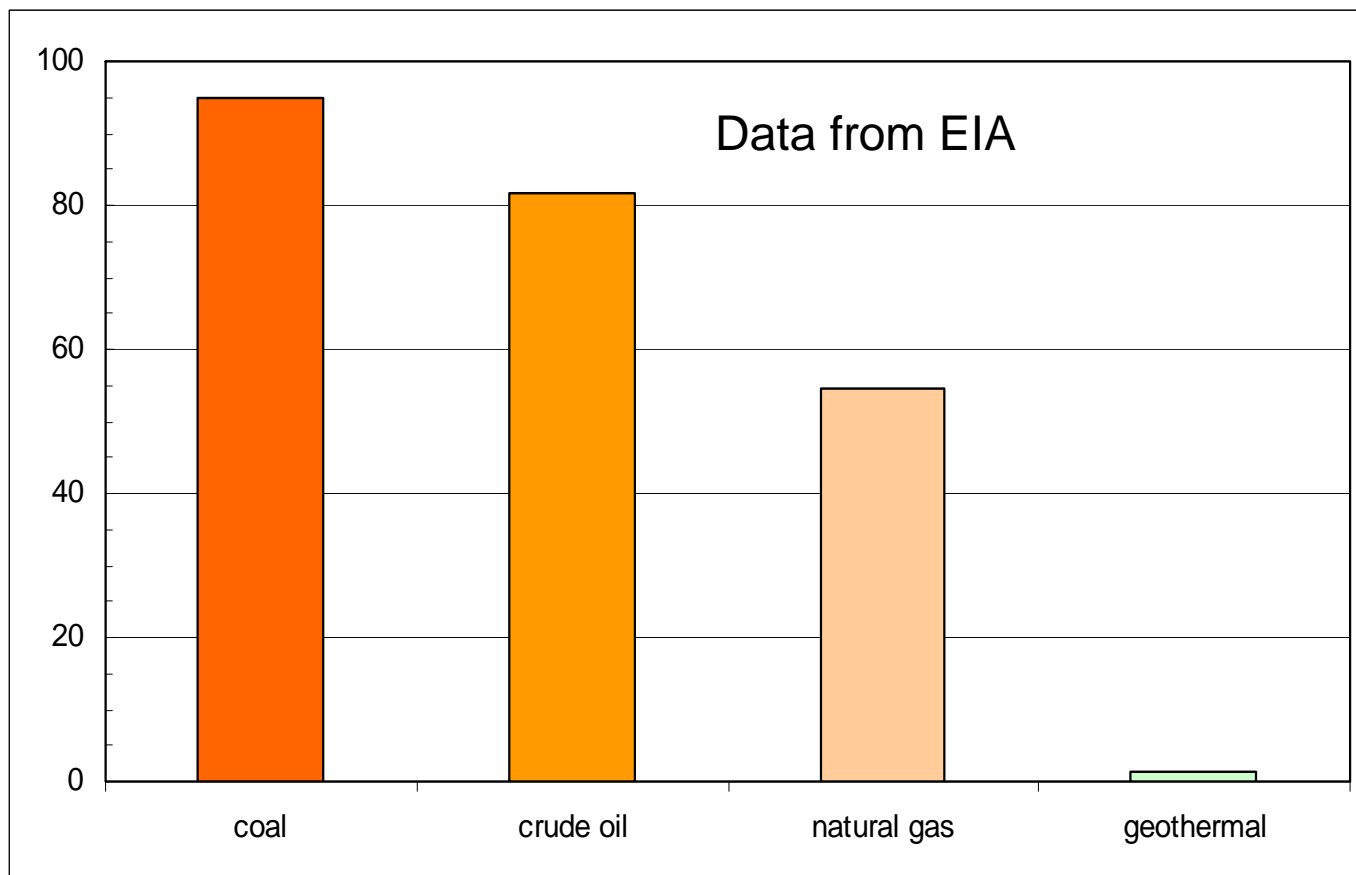


Energy Issues (Global Warming)

Geothermal Energy – A Low-Carbon Fuel

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

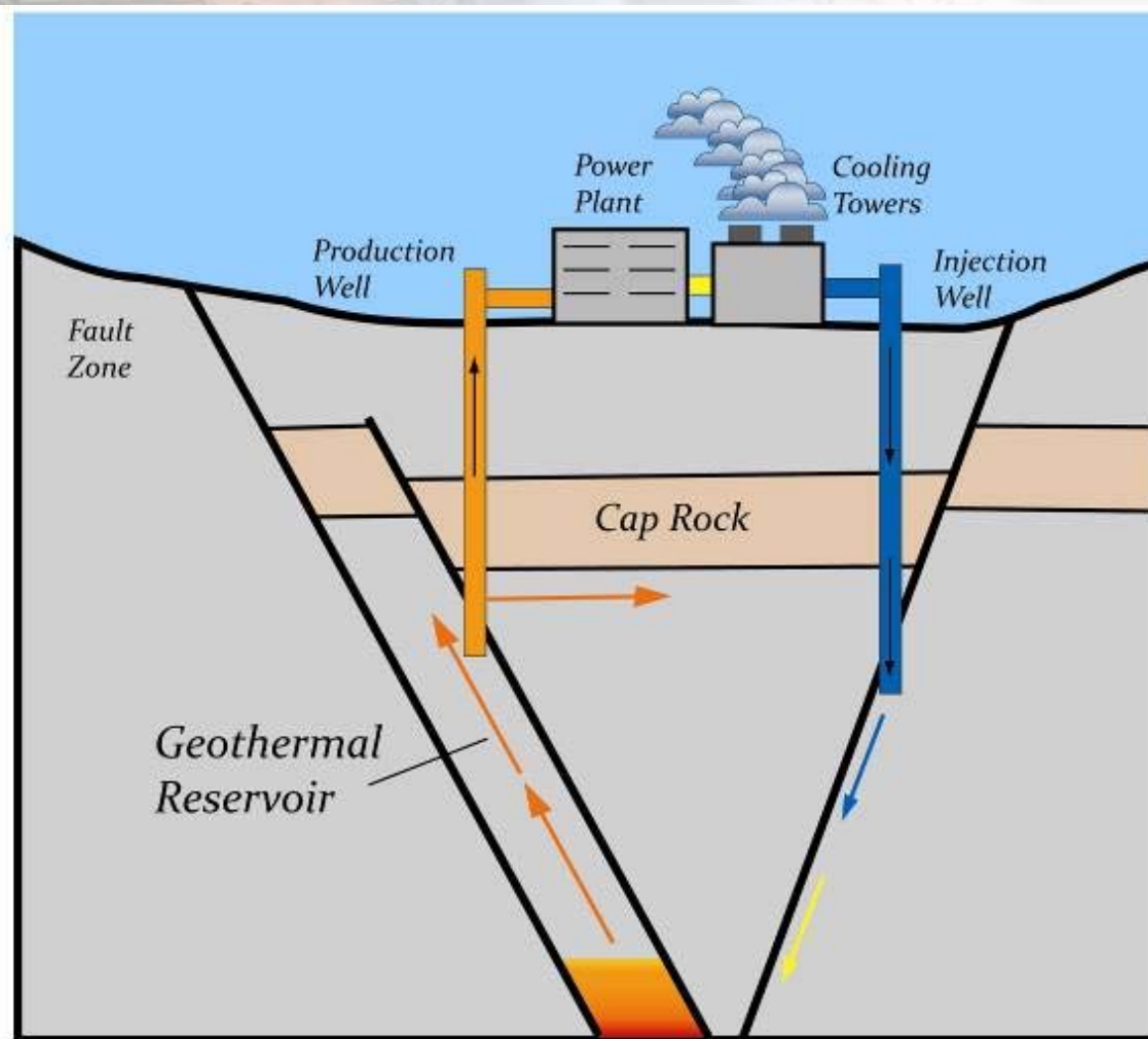
Million Metric
Tons CO₂
Emitted per
Quad Energy
(Fuel)
Consumed for
Electric Power
Generation



Background on Geothermal Energy

Idealized Geothermal Power System

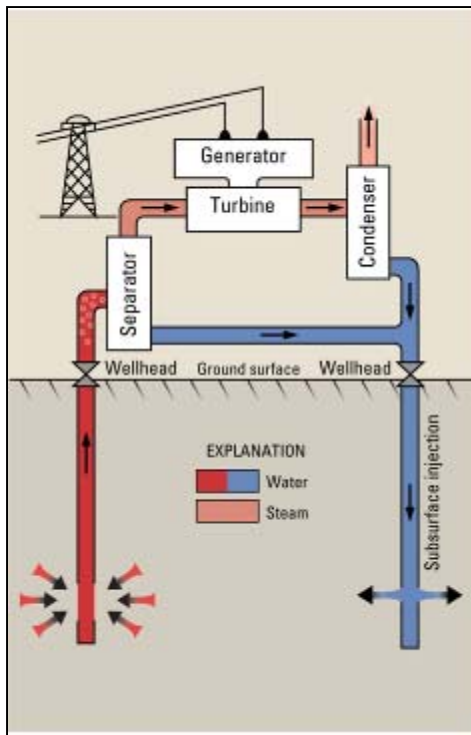
Needs:
Heat
(Temperature)
Fluid
(Water)
And
Permeability
(Fractures)



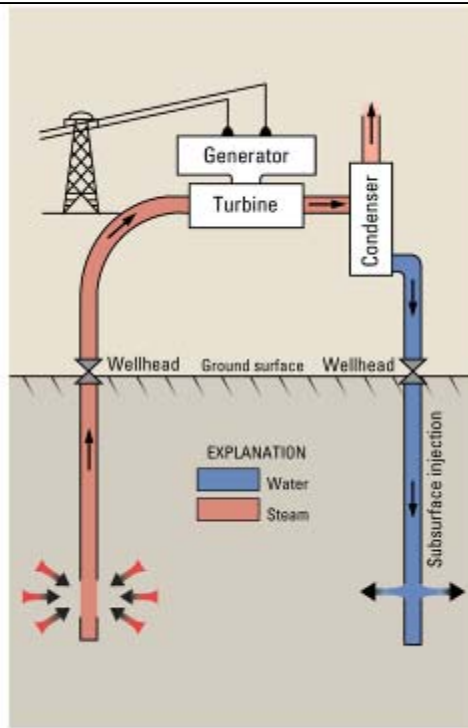
Background on Geothermal Energy

Electricity Generation from Geothermal Energy

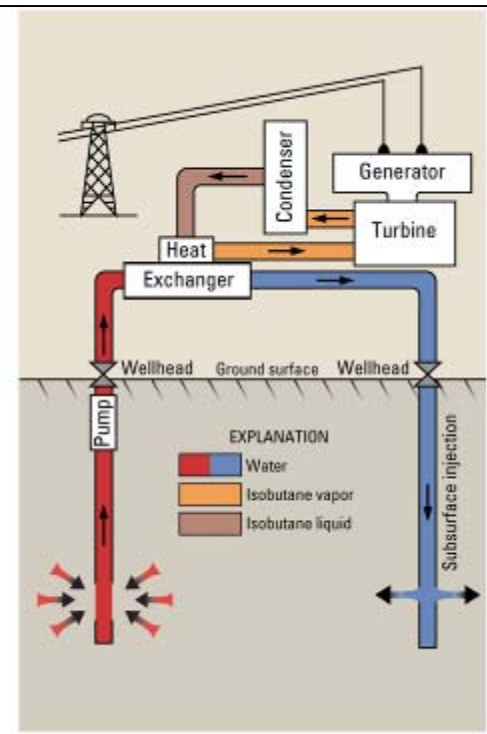
Hot water flash



Steam



Binary



Status of Geothermal Energy

1978 USGS Geothermal Resource Assessment (USGS Circular 790)

- **23,000 MWe** in identified systems
- **~100,000 MWe** in undiscovered systems
- 1978-2009 Geothermal Development
 - **2500 Megawatts-electric (MWe)** installed Geothermal generation capacity
 - **~15,000 Gigawatt-hours (GWh)** Geothermal power generated in 2005
- How do 30 years of research and development alter resource estimates?

USGS National Geothermal Resource Assessment

Scientific and Technological Developments

USGS Circular 790 (1978)

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 (2009)

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

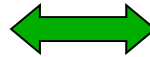
241 identified moderate and high temperature systems

Abundant exploration and production data for some systems

Improved models for reservoir performance

Better quantitative estimates of undiscovered resources

Enhanced Geothermal Systems included





USGS National Geothermal Resource Assessment

- Mandated in Energy Policy Act of 2005
- 3-year Effort Funded in FY-2006
- DOE Support for Cooperative Projects in FY-2005-2008
- 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 Geothermal Systems (EGS)*



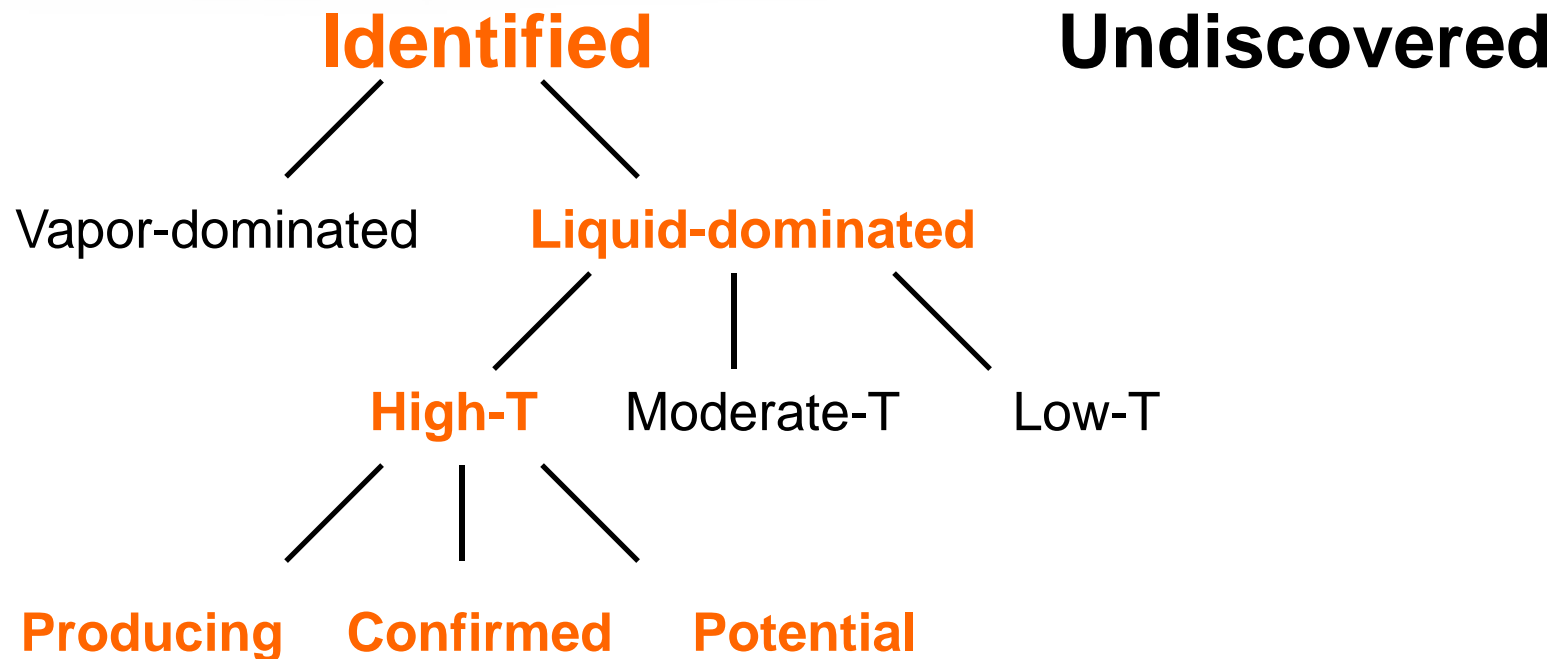
USGS National Geothermal Resource Assessment

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

USGS National Geothermal Resource Assessment

Geothermal Resource Categories

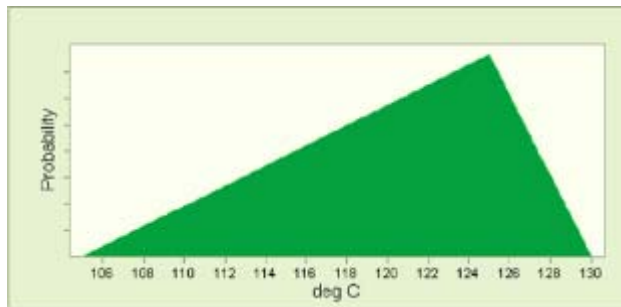


Only terms highlighted in **orange** show complete categories. Others follow similar subdivisions (e.g., high, moderate or low temperature). By definition, undiscovered resources cannot be subdivided into producing, confirmed or potential.

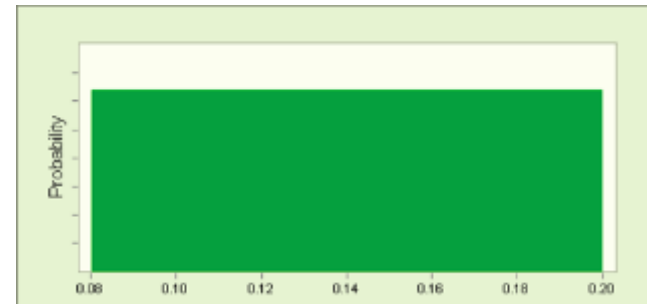
USGS National Geothermal Resource Assessment

Monte Carlo Simulation of Geothermal Resources

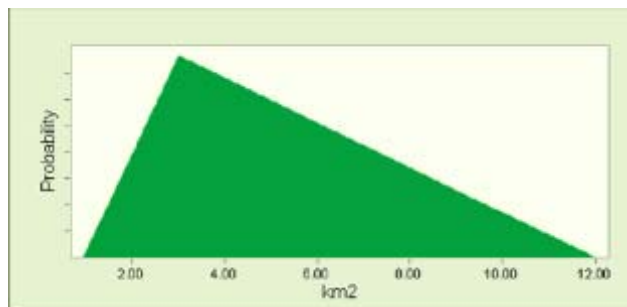
Reservoir Temperature



Recovery Factor

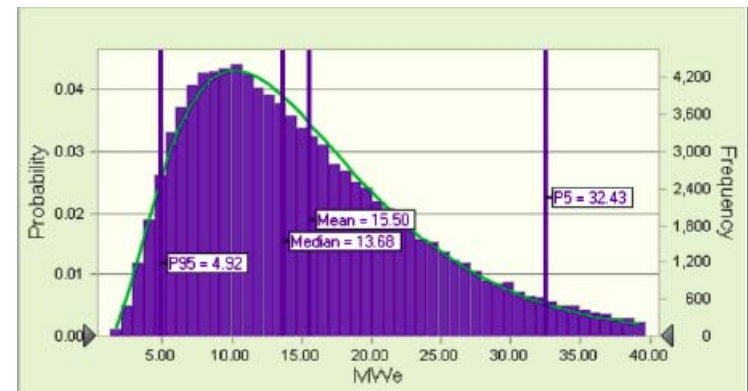


Reservoir Volume



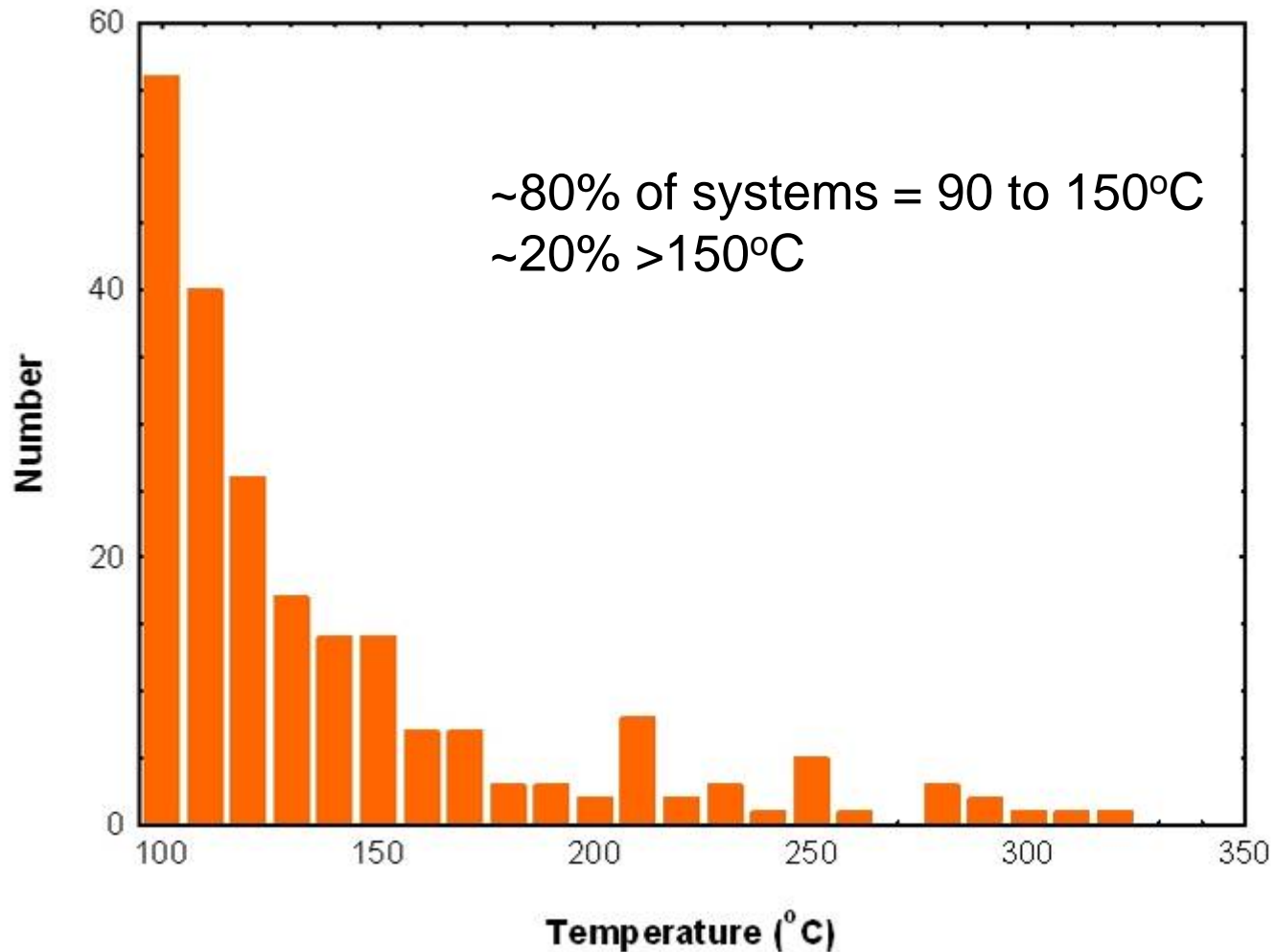
Reservoir
Thermal
Energy

Electric Power



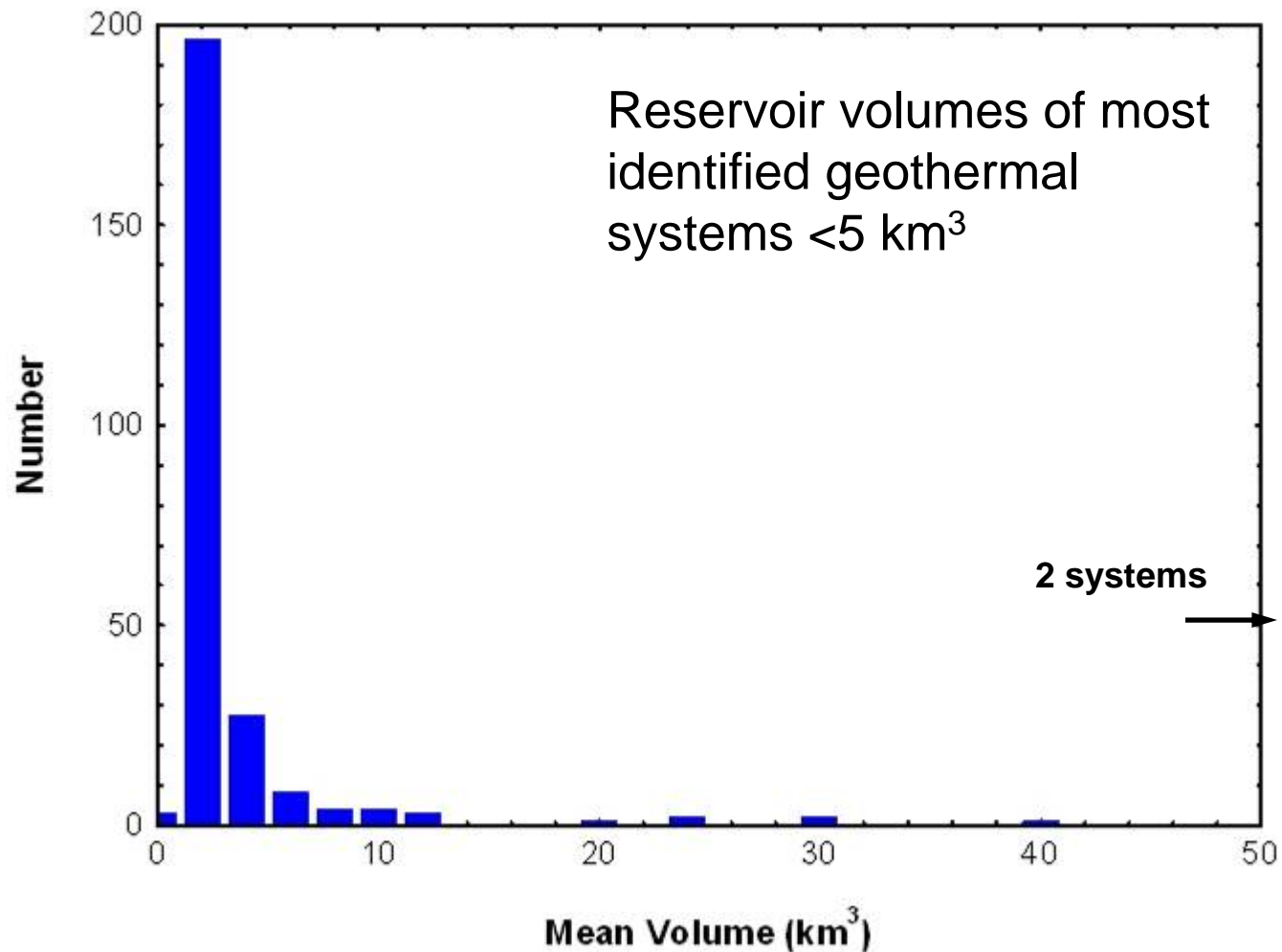
USGS National Geothermal Resource Assessment

Temperature Distribution of Identified Systems



USGS National Geothermal Resource Assessment

Volume Distribution of Identified Systems



USGS National Geothermal Resource Assessment

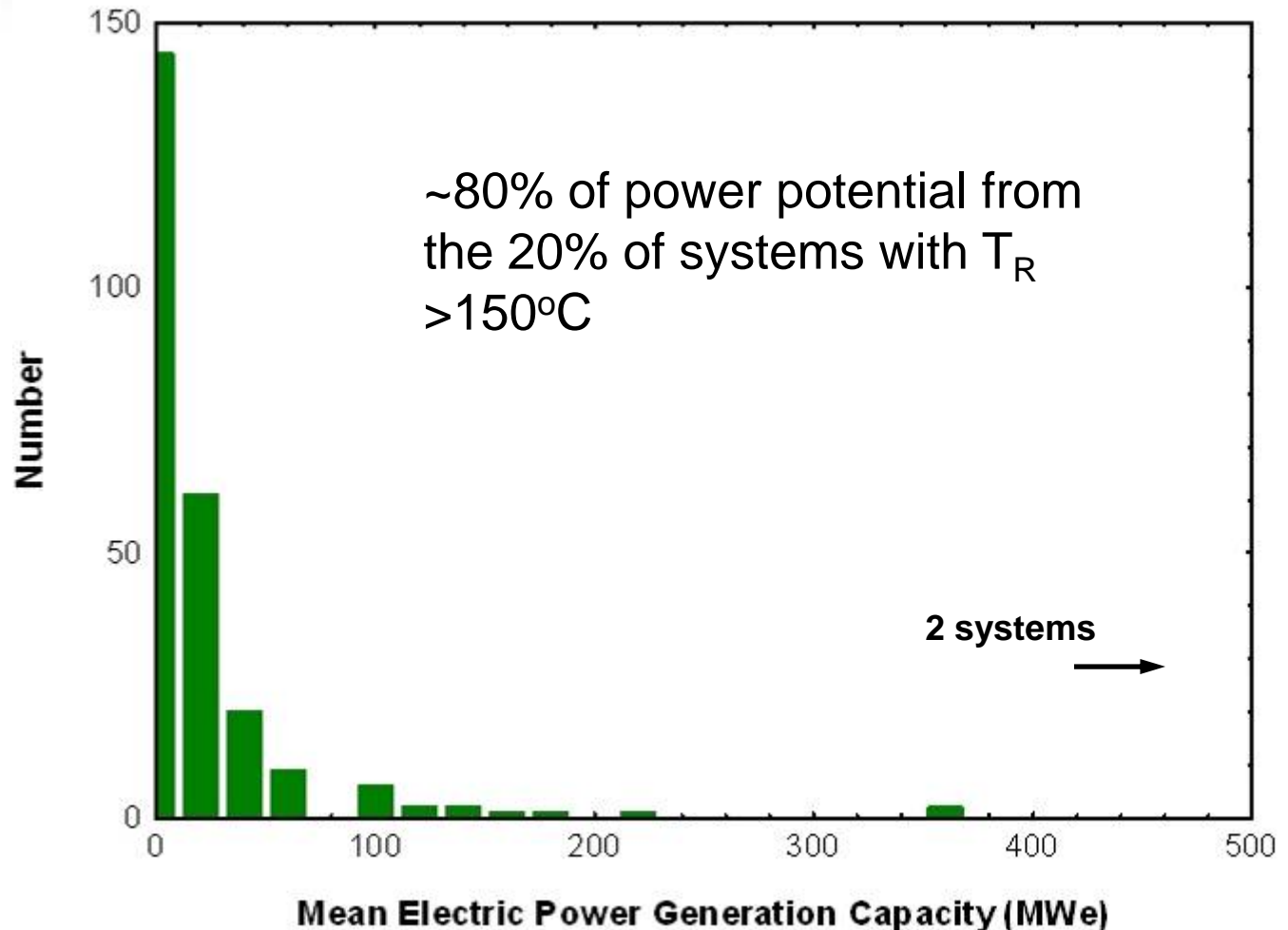
Power Distribution of Identified Systems

Identified Systems
Potential –

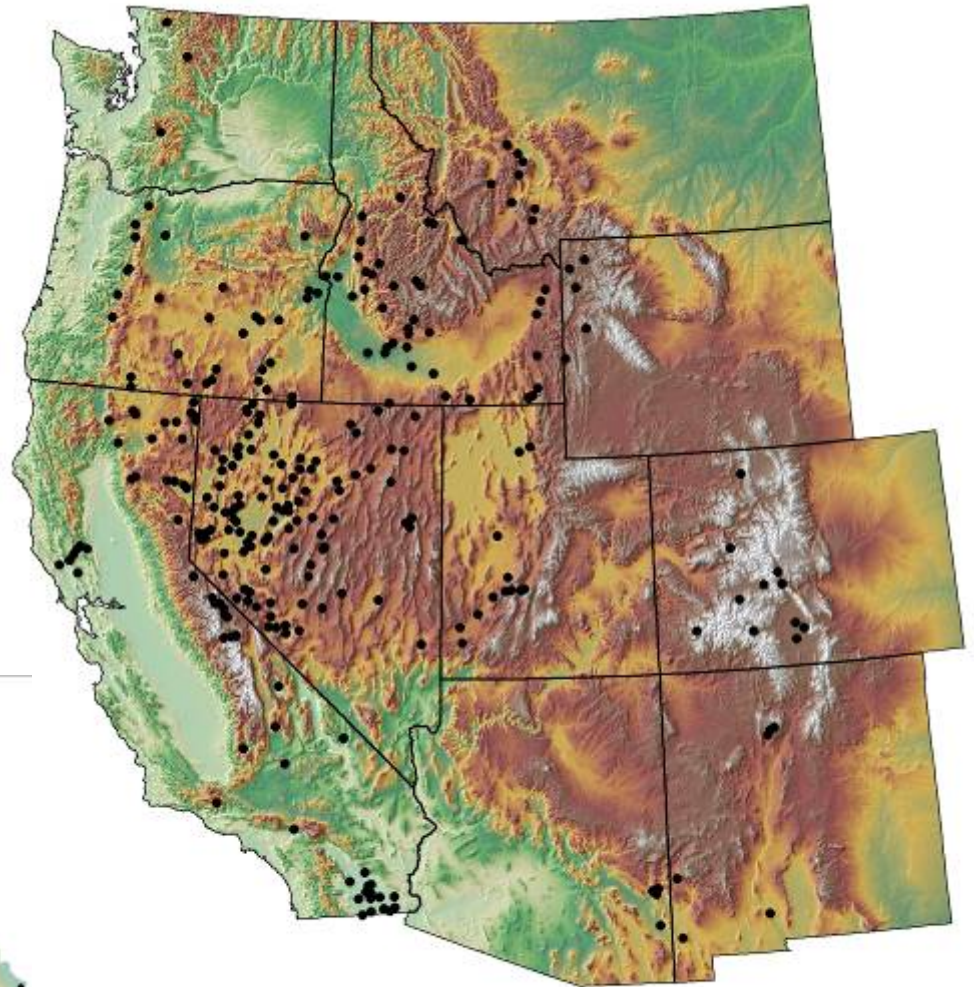
Mean = 9057 MWe

F95 = 3675 MWe

F5 = 16457 MWe



Results: Identified Geothermal Systems



Identified Geothermal Systems: New Mexico

Valles Caldera (Circular 790, 1978) = 2700 MW

Unocal Initial Baca Estimates (~1980) = 400 MW with partial injection
= 1200 MW with full injection

Our new estimate (2009) = 128 MW (including NW Sulphur Springs area)

Jemez Spring = 9 MW

Montezuma Hot Spring = 5 MW

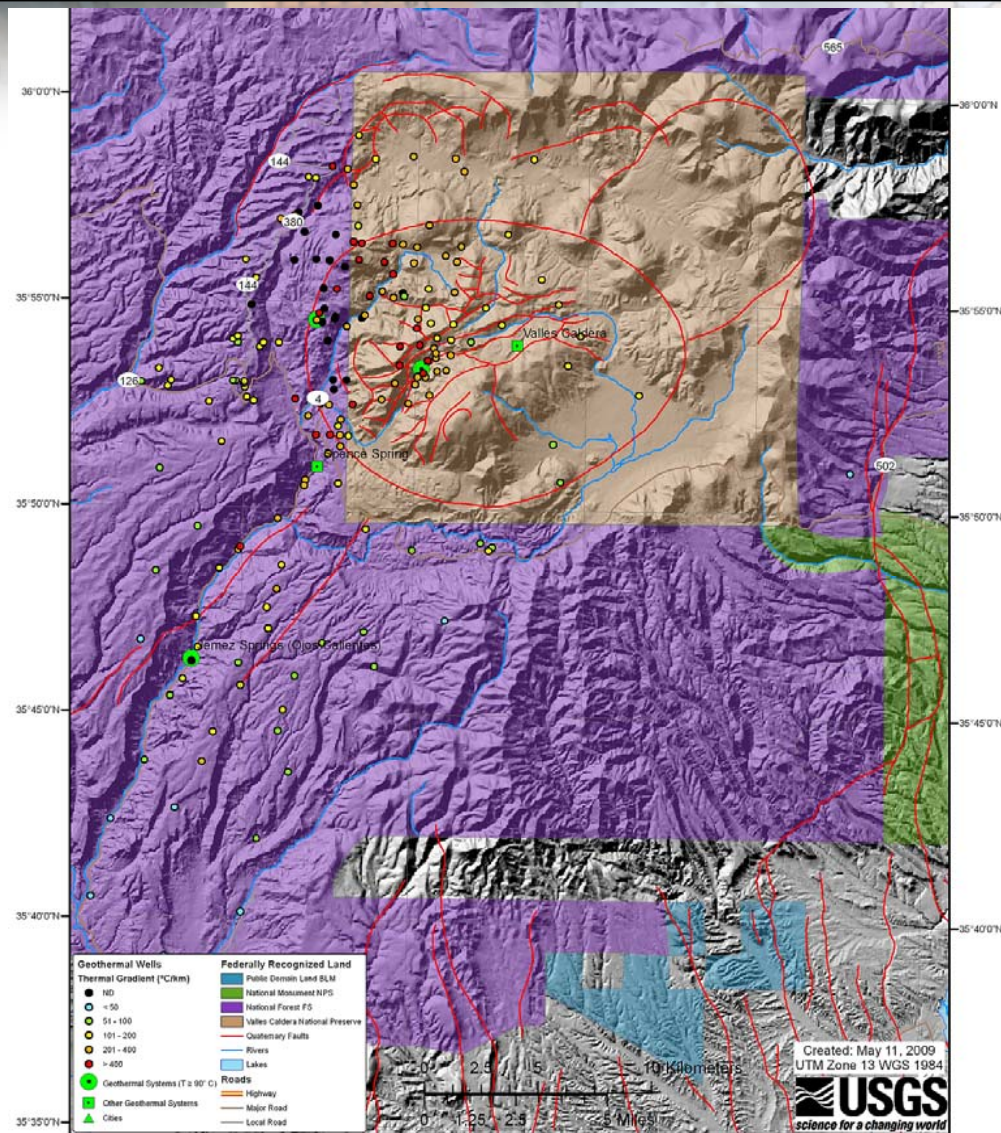
Gila Hot Spring = 5 MW

Radium Hot Springs = 8 MW

Lightning Dock = 15 MW

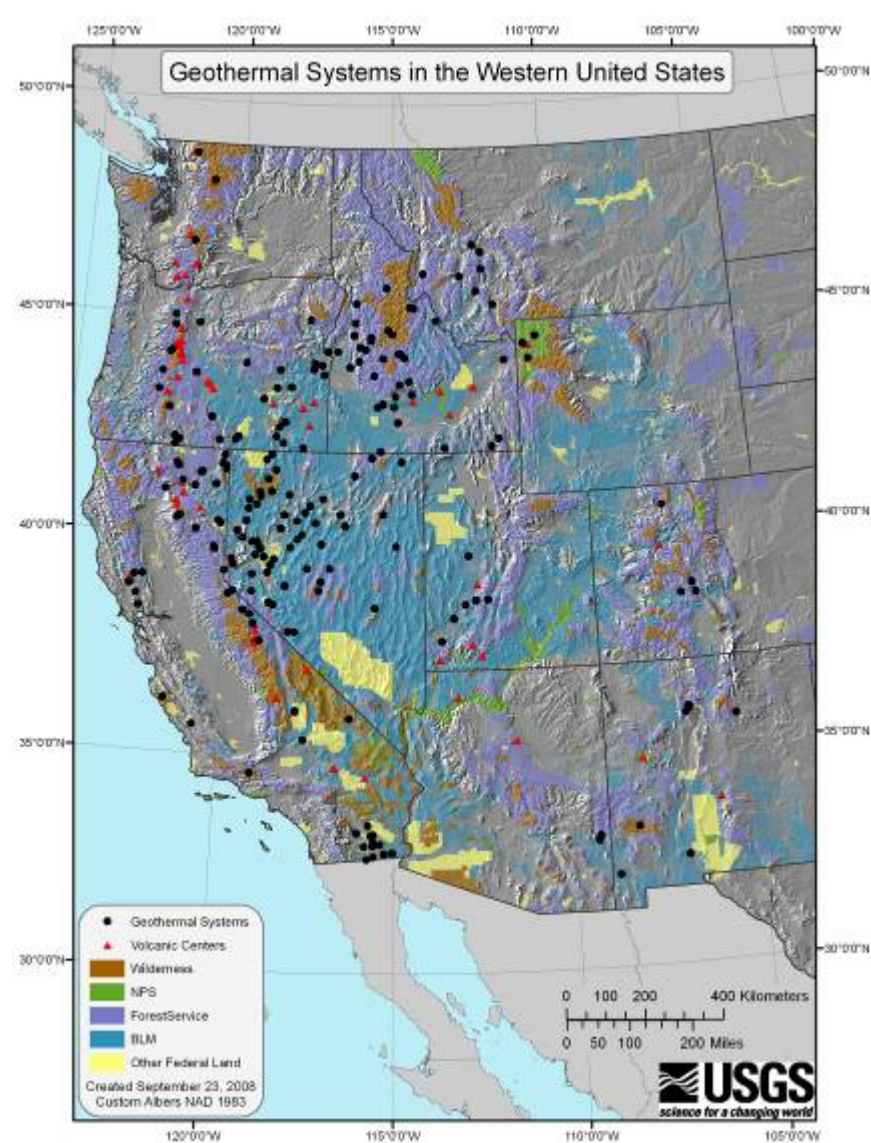
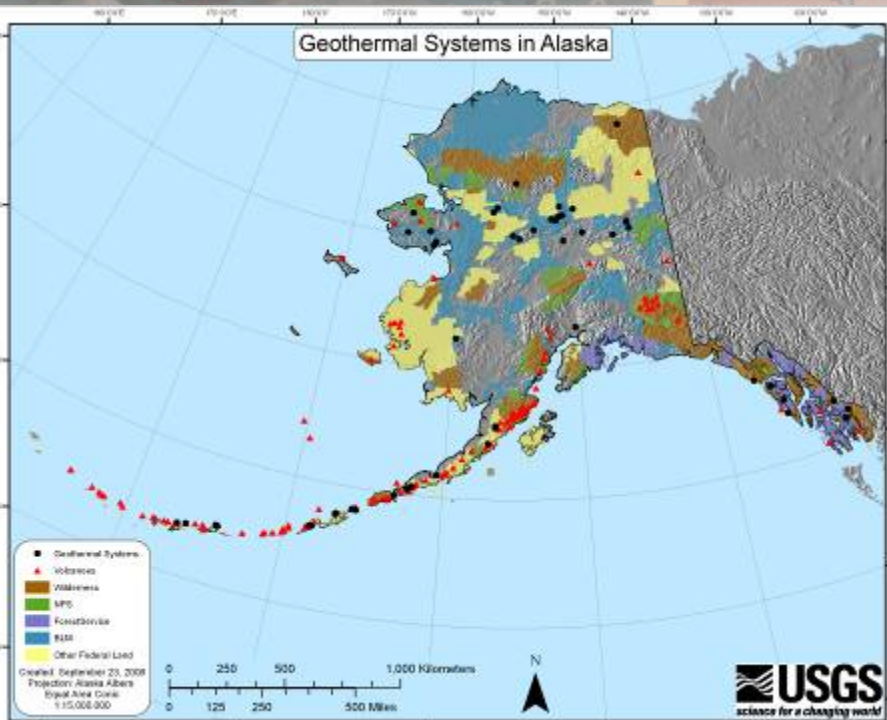
Identified Geothermal Systems

Geothermal Systems and Land Status



Identified Geothermal Systems

Geothermal Systems and Land Status



Undiscovered Resources – Weights of Evidence

The Weights-of-Evidence approach employs probability to determine the degree of correlation among spatial databases. This measure of correlation can be used to produce maps of favorability for the occurrence of features of interest. The technique has been used to study the spatial relationship of deposits to evidence layers through the use of Geographic Information Systems (GIS).

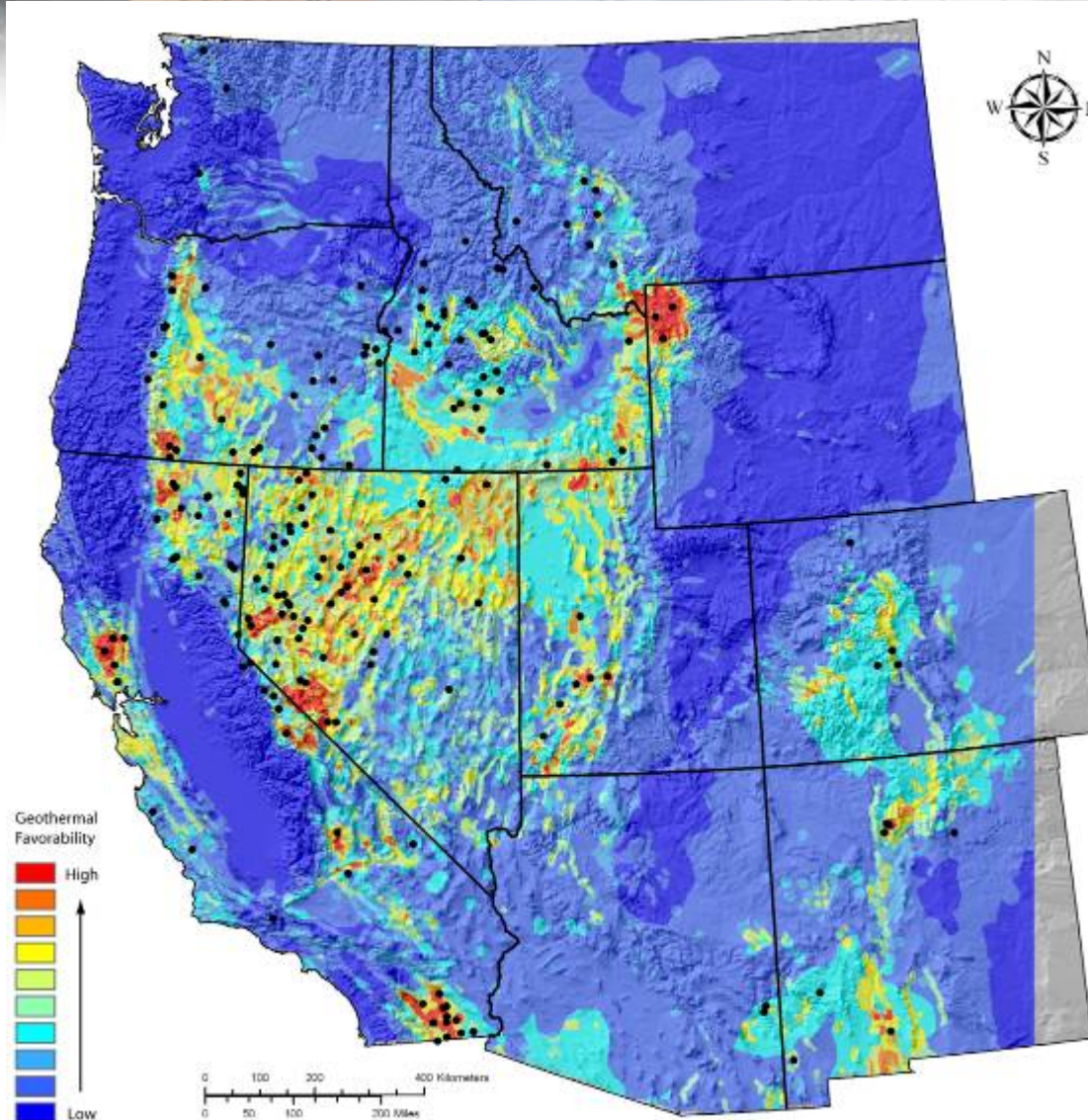
Prior probability – *Derived from knowledge that is present before a particular observation is made.*

Posterior probability – *Derived from knowledge developed once the outcome of the observation is taken into account.*

Positive and negative weights are assigned which represent the degree of correlation between evidence layers and occurrences.

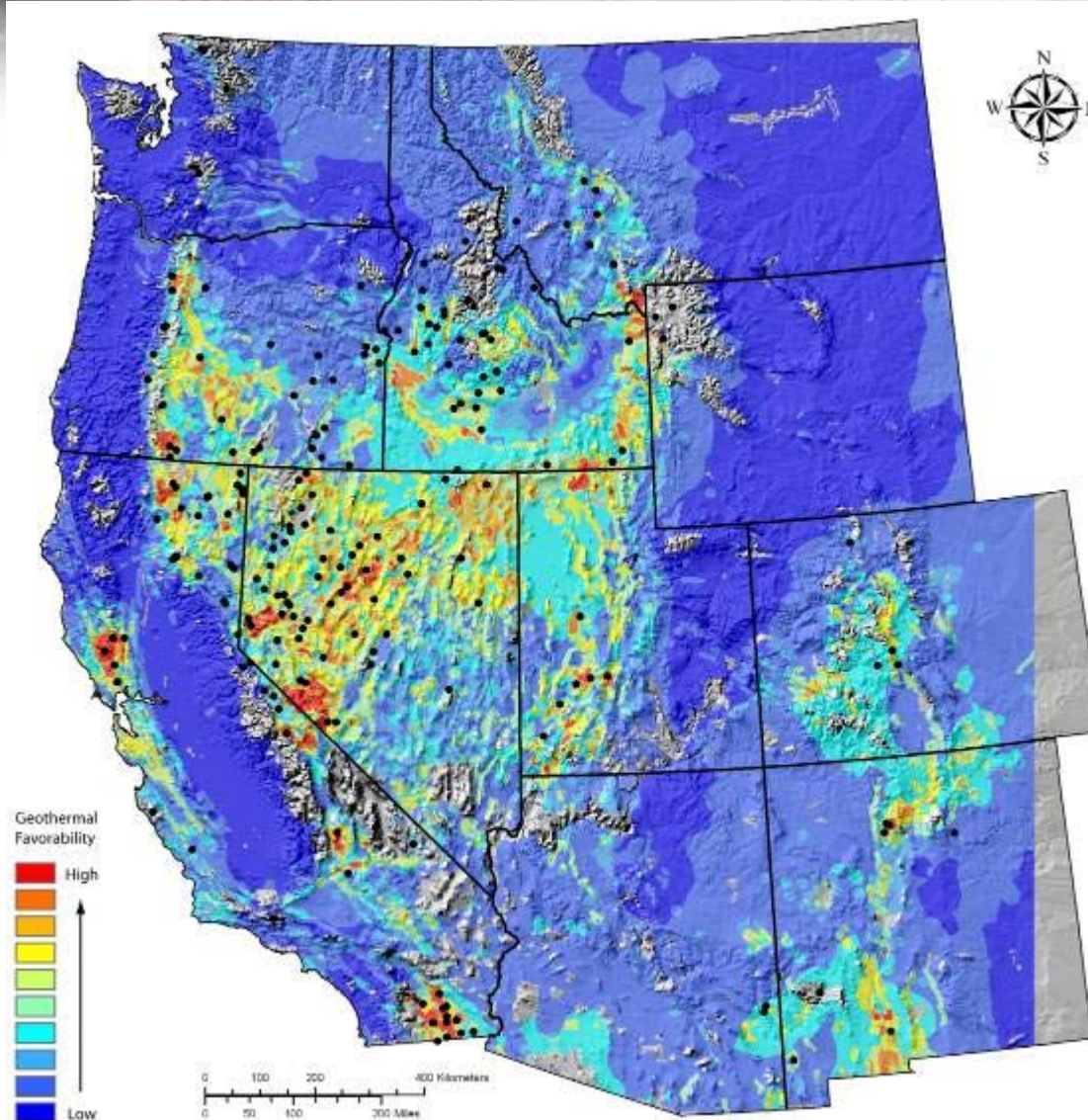
Undiscovered Resources – Geothermal Favorability Maps

Warmer colors represent high probability for the presence of geothermal systems



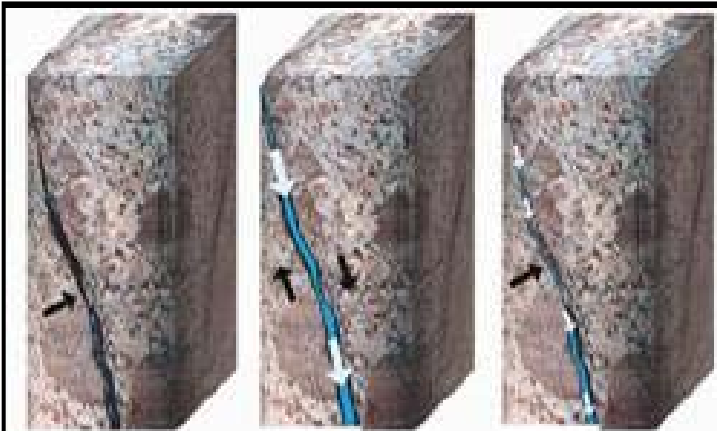
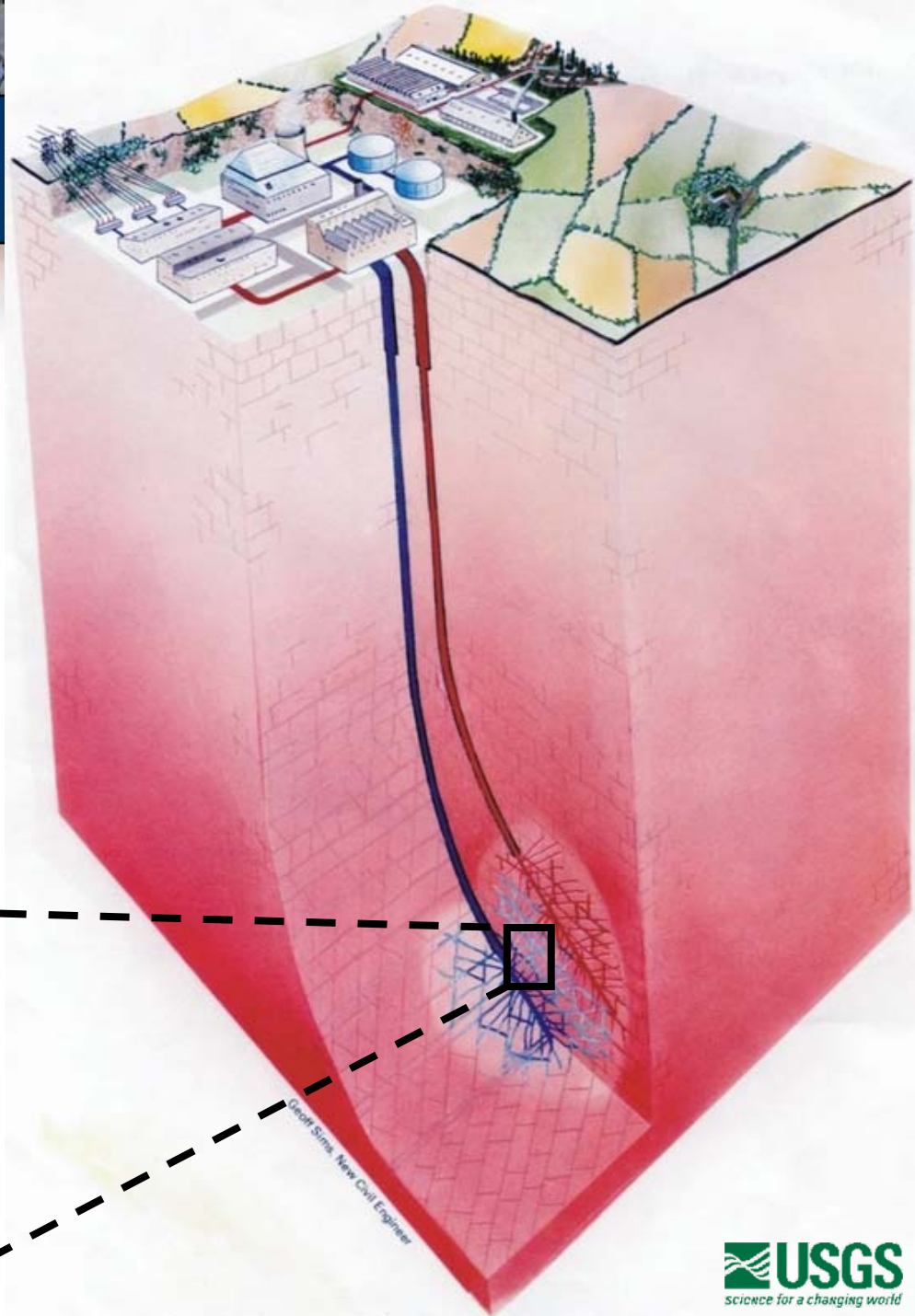
Undiscovered Resources – Effect of Closed Public Lands

Undiscovered
Resources –
Mean = 30,033 MWe
F95 = 7917 MWe
F5 = 73,286 MWe



Enhanced Geothermal Systems (EGS)

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

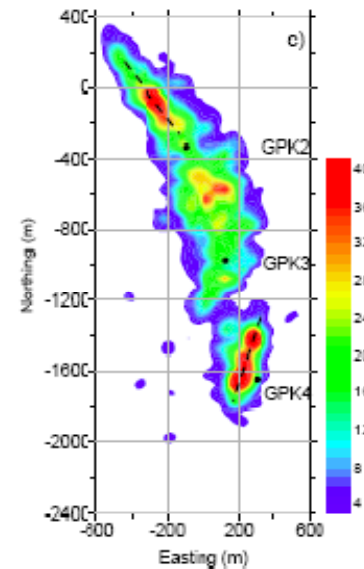
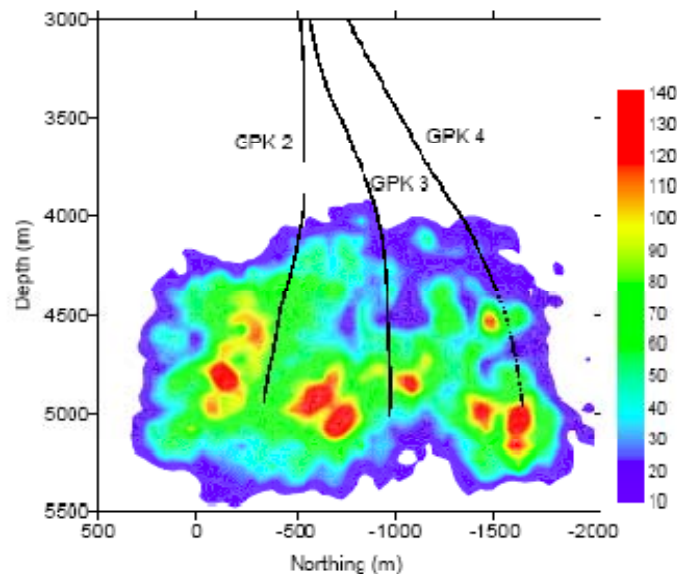




Enhanced Geothermal Systems

- 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

Soultz-sous-Forêts, France

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

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

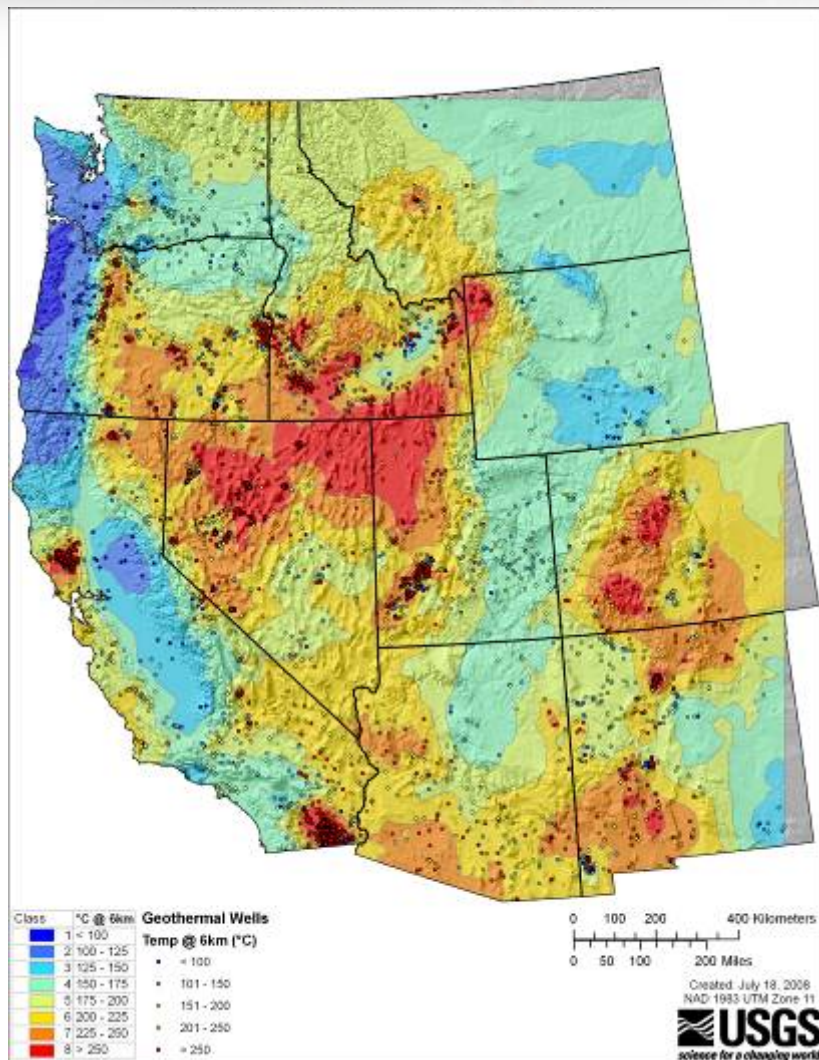
Potential Generation $\sim 1.5 \text{ MWe}$

(Tischner et al., 2007)

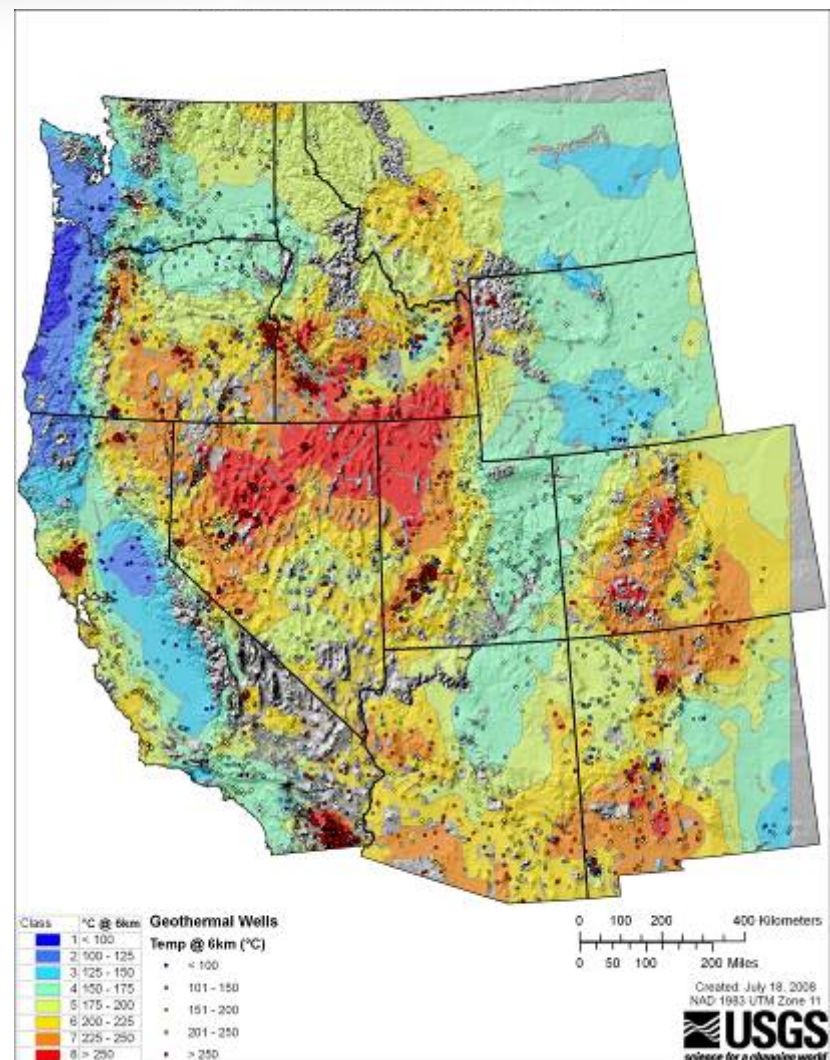


Enhanced Geothermal Systems – USGS Deep Temperatures

Temperature contours

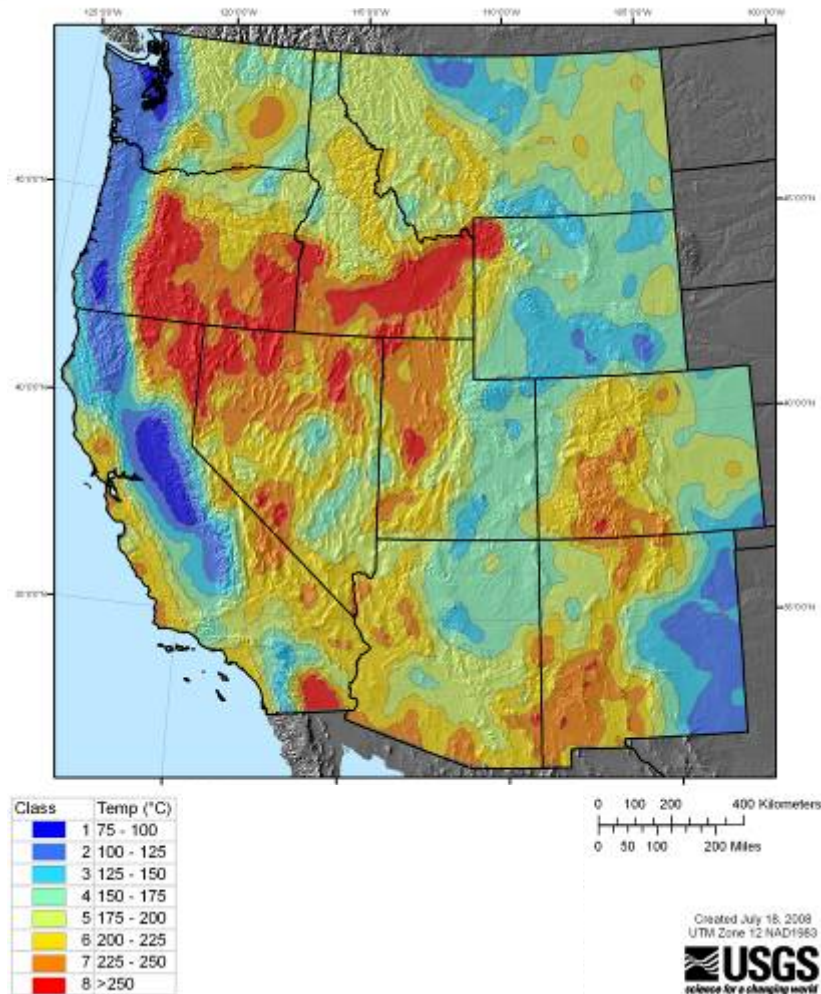


Temperature contours w/o closed public lands

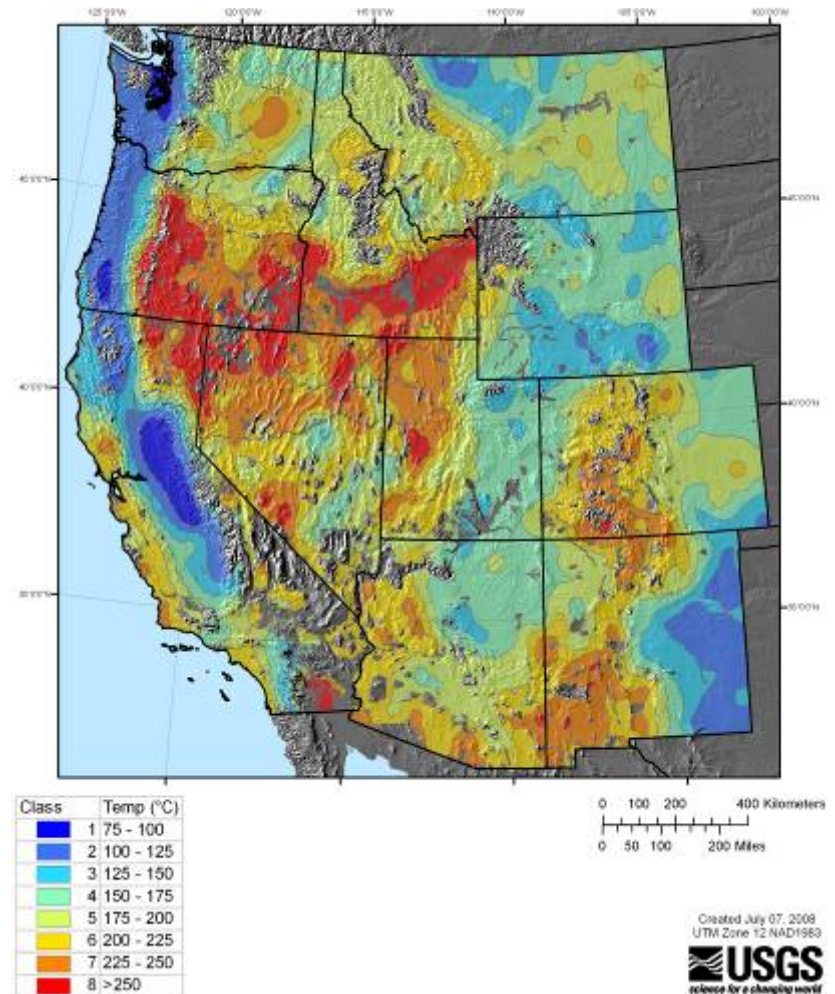


Enhanced Geothermal Systems – SMU Deep Temperatures

Temperature contours



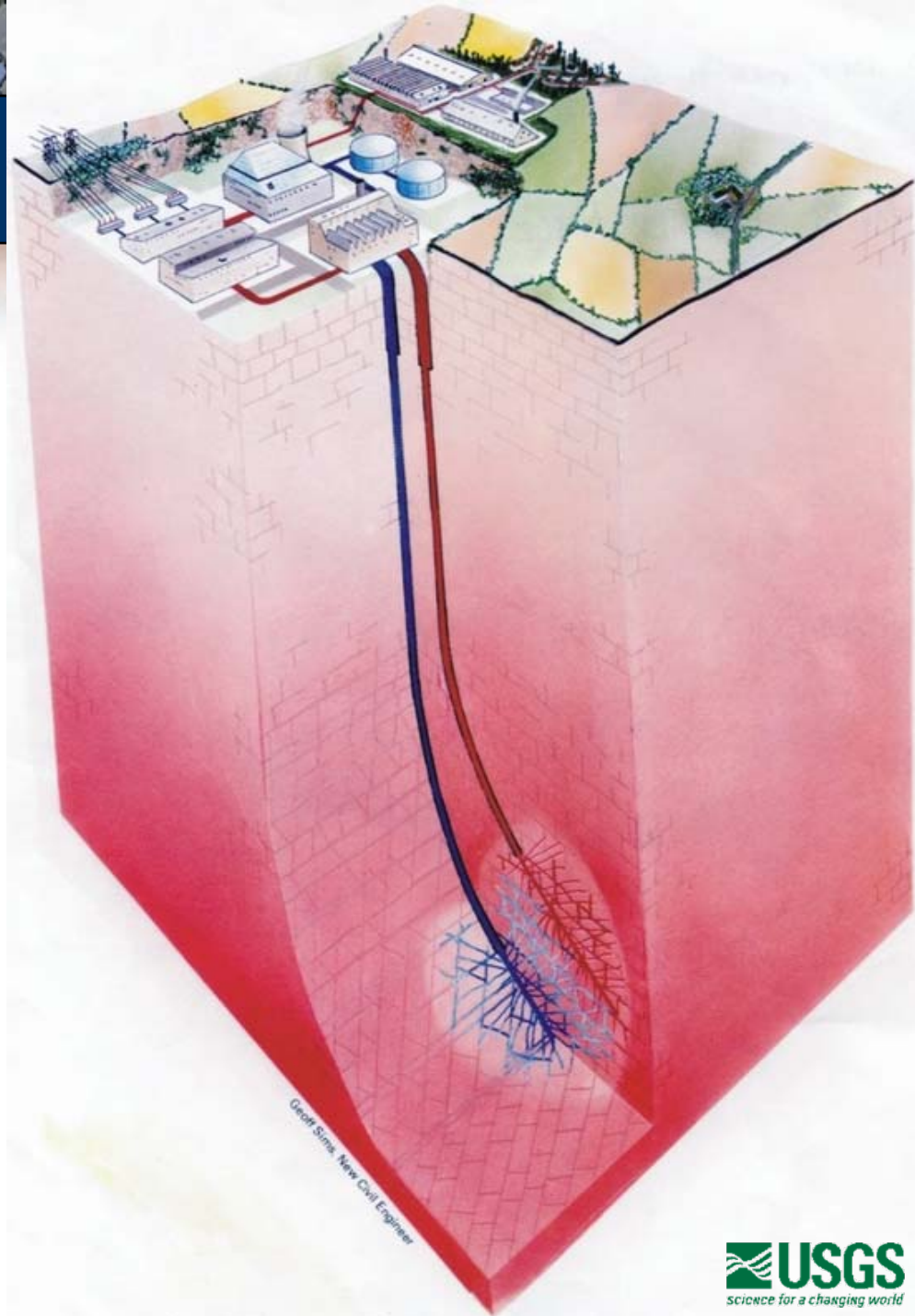
Temperature contours w/o closed public lands



Enhanced Geothermal Systems (EGS)

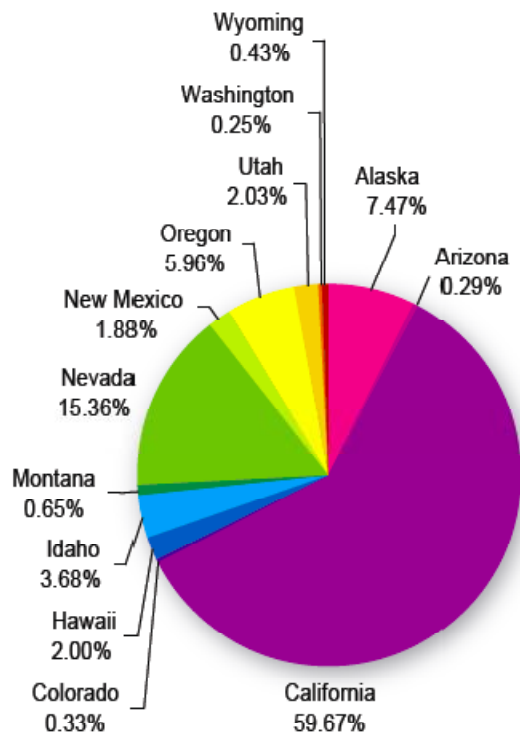
EGS Resources –
Mean = 517,800 MWe
F95 = 345,100 MWe
F5 = 727,900 MWe

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

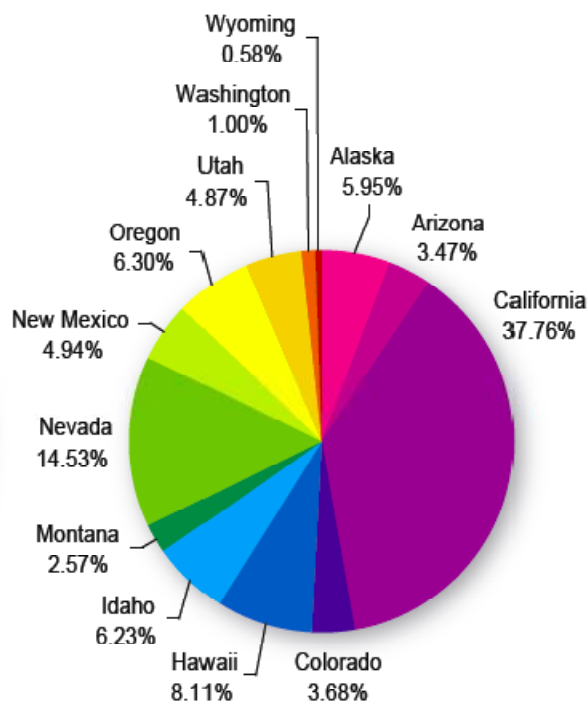


Distribution of Geothermal Potential

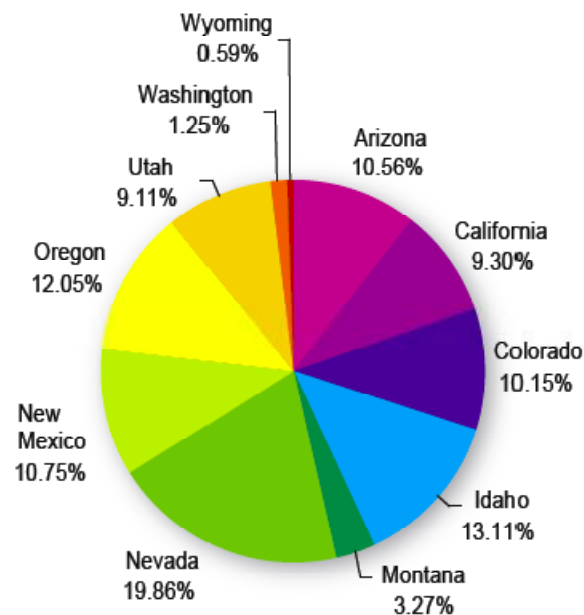
A. Identified Geothermal Resources



B. Undiscovered Resources



C. Enhanced Geothermal Systems



Future Assessment Work

- Publish Supporting Reports and Databases
- Update Assessment Results
- Improve 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 potentials are:
 - **Identified Geothermal Systems = 9,057 MWe** (distributed over 13 states)
 - **Undiscovered Geothermal Resources = 30,033 MWe.**
 - **Enhanced Geothermal Systems (EGS) = 517,800 MWe** could be generated from development of the technology for creating geothermal reservoirs in regions characterized by high temperature, but low permeability, rock formations.

Acknowledgements

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Ingebritsen, David Ponce, Claire Bouligand, Fred Grubb, Patrick
Muffler, John Sass, Art Lachenbruch, Angela Jayko**

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Thank You



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