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

- **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
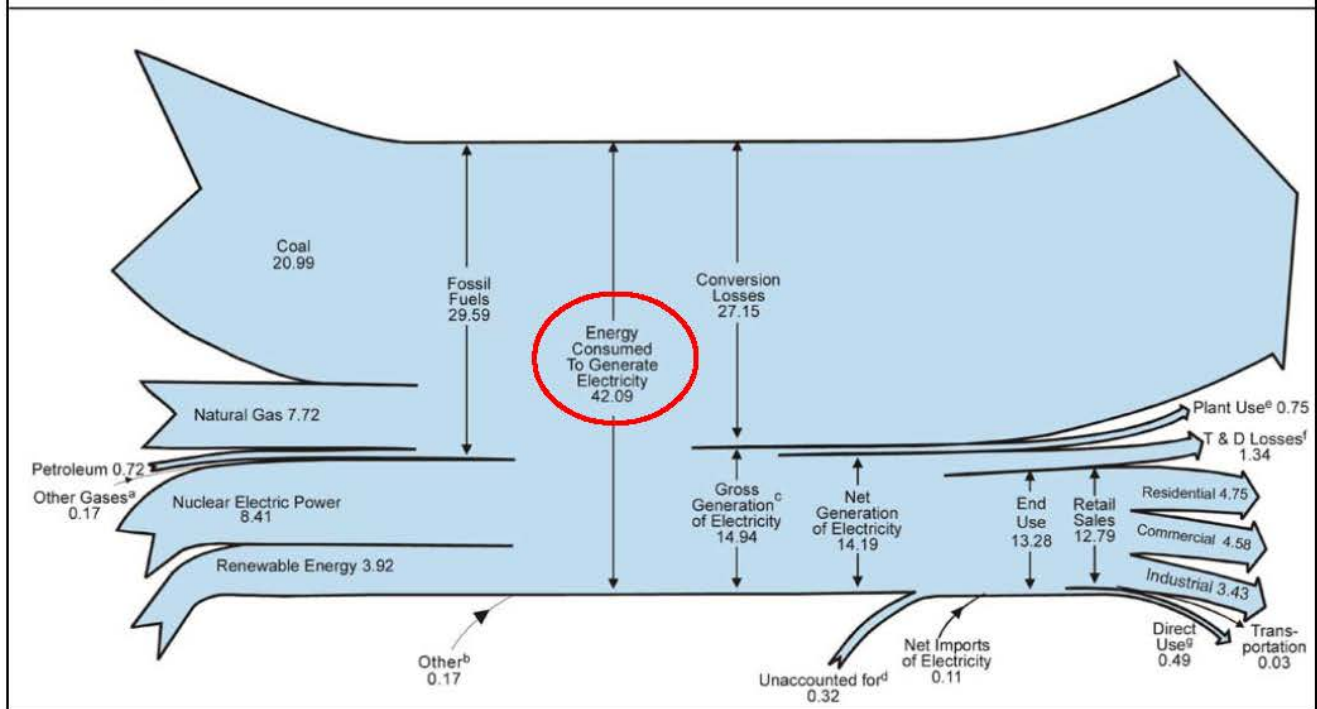- Summary

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.
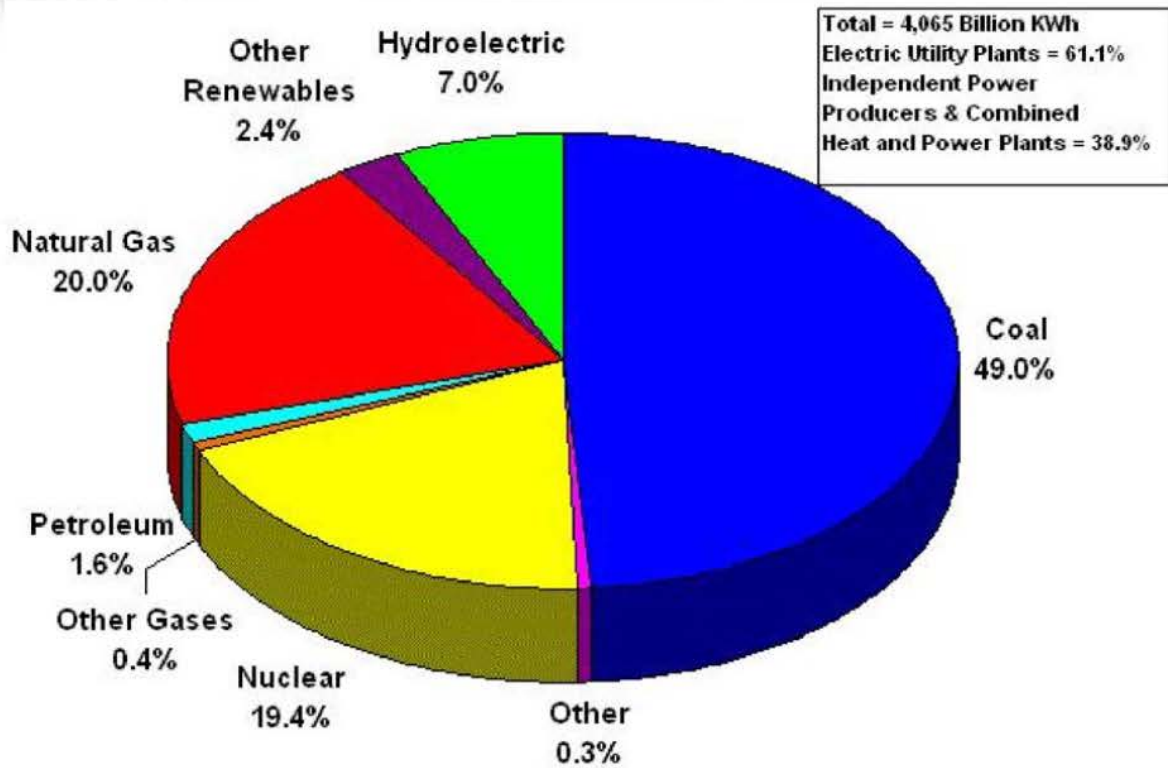
U.S. Electric Power Generation Mix

Diagram 5. Electricity Flow, 2007
(Quadrillion Btu)

- Coal 20.99
- Fossil Fuels 29.59
- Natural Gas 7.72
- Petroleum 0.72
- Other Gases[a] 0.17
- Nuclear Electric Power 8.41
- Renewable Energy 3.92
- Other[b] 0.17
- Energy Consumed To Generate Electricity 42.09
- Conversion Losses 27.15
- Gross Generation[c] of Electricity 14.94
- Net Generation of Electricity 14.19
- Unaccounted for[d] 0.32
- Net Imports of Electricity 0.11
- End Use 13.28
- Retail Sales 12.79
- Plant Use[e] 0.75
- T & D Losses[f] 1.34
- Residential 4.75
- Commercial 4.58
- Industrial 3.43
- Direct Use[g] 0.49
- Transportation 0.03

Other Renewables 2.4%

Hydroelectric 7.0%

Natural Gas 20.0%

Petroleum 1.6%

Other Gases 0.4%

Nuclear 19.4%

Other 0.3%

Coal 49.0%

Total = 4,065 Billion KWh
Electric Utility Plants = 61.1%
Independent Power
Producers & Combined
Heat and Power Plants = 38.9%

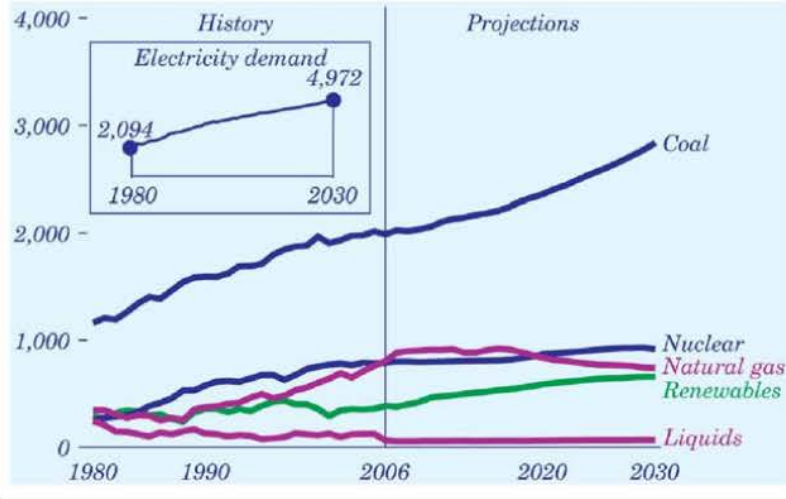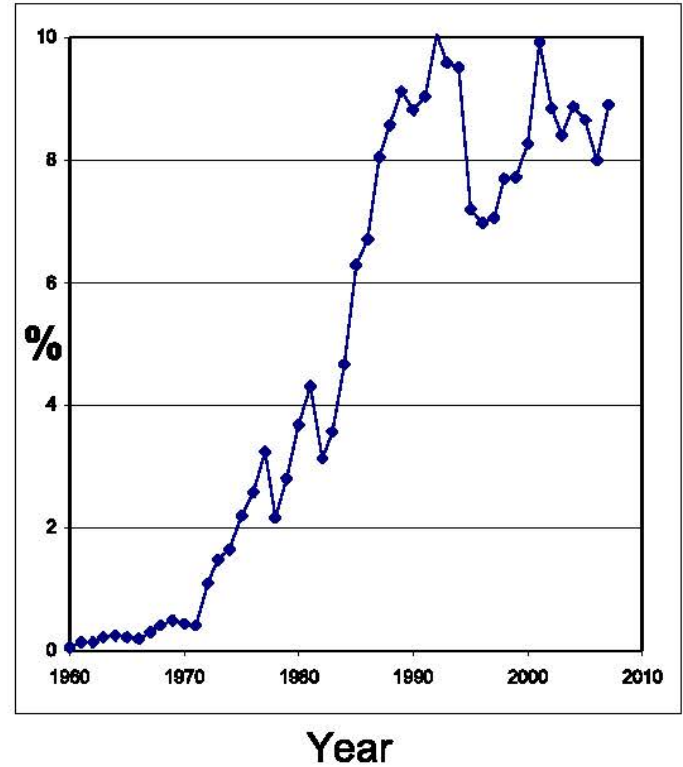http://www.eia.doe.gov/cneaf/electricity/epa/figes1.html

Geothermal and Future U.S. Electric Power Generation

Can geothermal help meet future electric power demands?
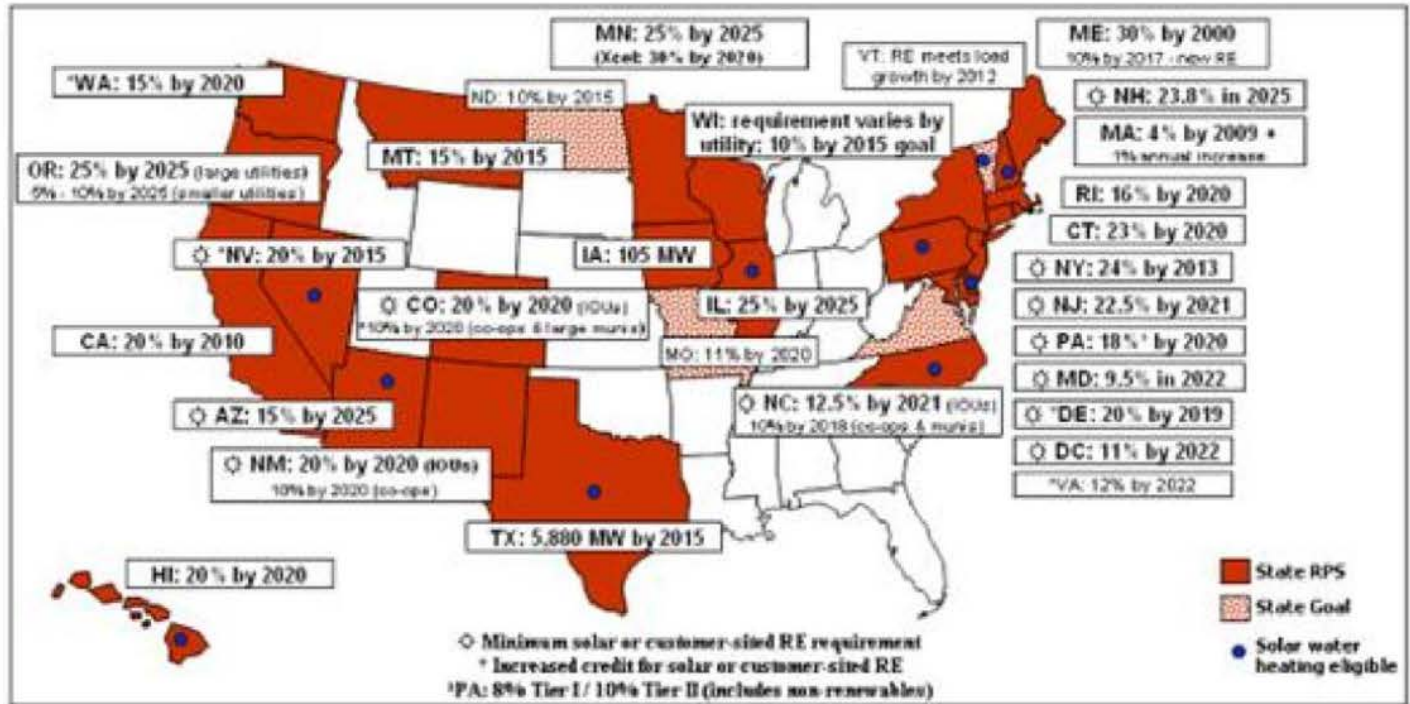
Figure 7. Electricity generation by fuel, 1980-2030 (billion kilowatthours)

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

Year

Figure 1.11. Renewables Portfolio Standards

MN: 25% by 2025 (Xcel: 30% by 2020)

VT: RE meets load growth by 2012

ME: 30% by 2000 10% by 2017 - new RE

*WA: 15% by 2020

ND: 10% by 2015

WI: requirement varies by utility: 10% by 2015 goal

◇ NH: 23.8% in 2025

MA: 4% by 2009 * 1% annual increase

OR: 25% by 2025 (large utilities) 5% - 10% by 2025 (smaller utilities)

MT: 15% by 2015

RI: 16% by 2020

CT: 23% by 2020

◇ *NV: 20% by 2015

IA: 105 MW

IL: 25% by 2025

◇ NY: 24% by 2013

◇ CO: 20% by 2020 (IOUs) *10% by 2020 (co-ops & large munis)

◇ NJ: 22.5% by 2021

CA: 20% by 2010

MO: 11% by 2020

◇ PA: 18%* by 2020

◇ MD: 9.5% in 2022

◇ AZ: 15% by 2025

◇ NC: 12.5% by 2021 (IOUs) 10% by 2018 (co-ops & munis)

◇ *DE: 20% by 2019

◇ NM: 20% by 2020 (IOUs) 10% by 2020 (co-ops)

◇ DC: 11% by 2022

*VA: 12% by 2022

TX: 5,880 MW by 2015

HI: 20% by 2020

■ State RPS

▨ State Goal

● Solar water heating eligible

◇ Minimum solar or customer-sited RE requirement
* Increased credit for solar or customer-sited RE
¹PA: 8% Tier I / 10% Tier II (includes non-renewables)

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Need: Heat (Temperature) and Fluid (Permeability)

Power Plant

Cooling Towers

Production Well

Injection Well

Fault Zone

Cap Rock

Geothermal Reservoir

Electricity Generation from Geothermal Energy

Source: USGS Circular 1249
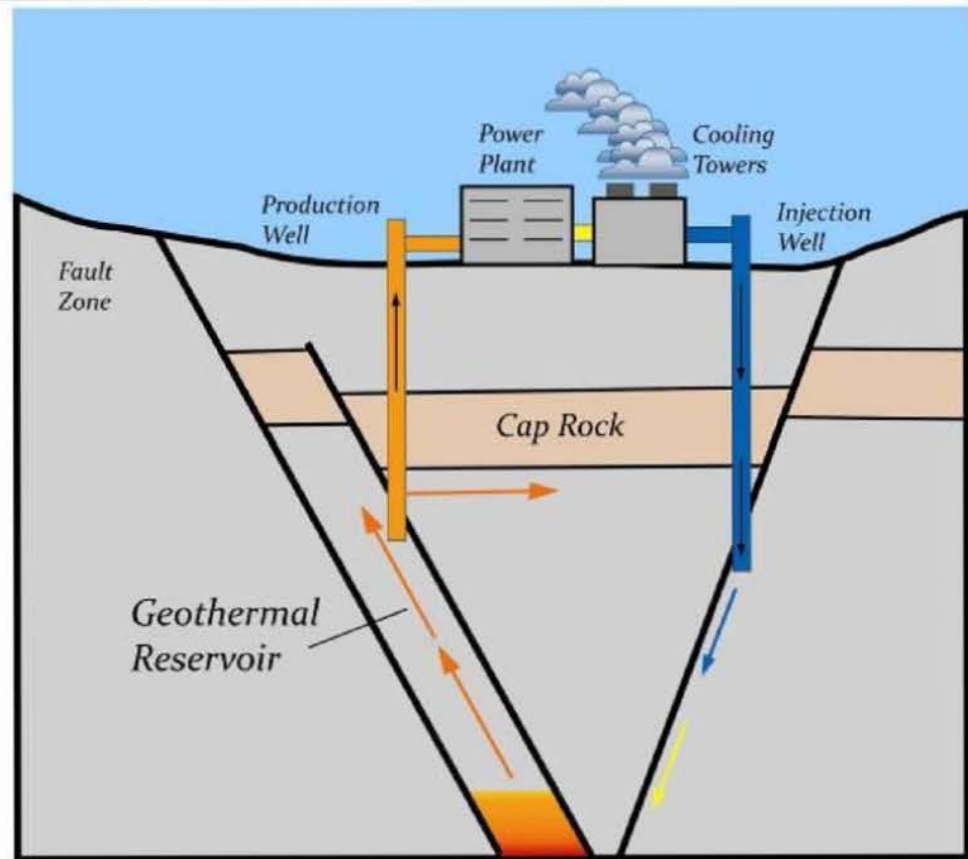
Geothermal Energy – A Low-Carbon Fuel

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

Data from EIA

coal	crude oil	natural gas	geothermal

(Chart y-axis: 0 to 100; coal ≈ 95, crude oil ≈ 82, natural gas ≈ 55, geothermal ≈ 1)
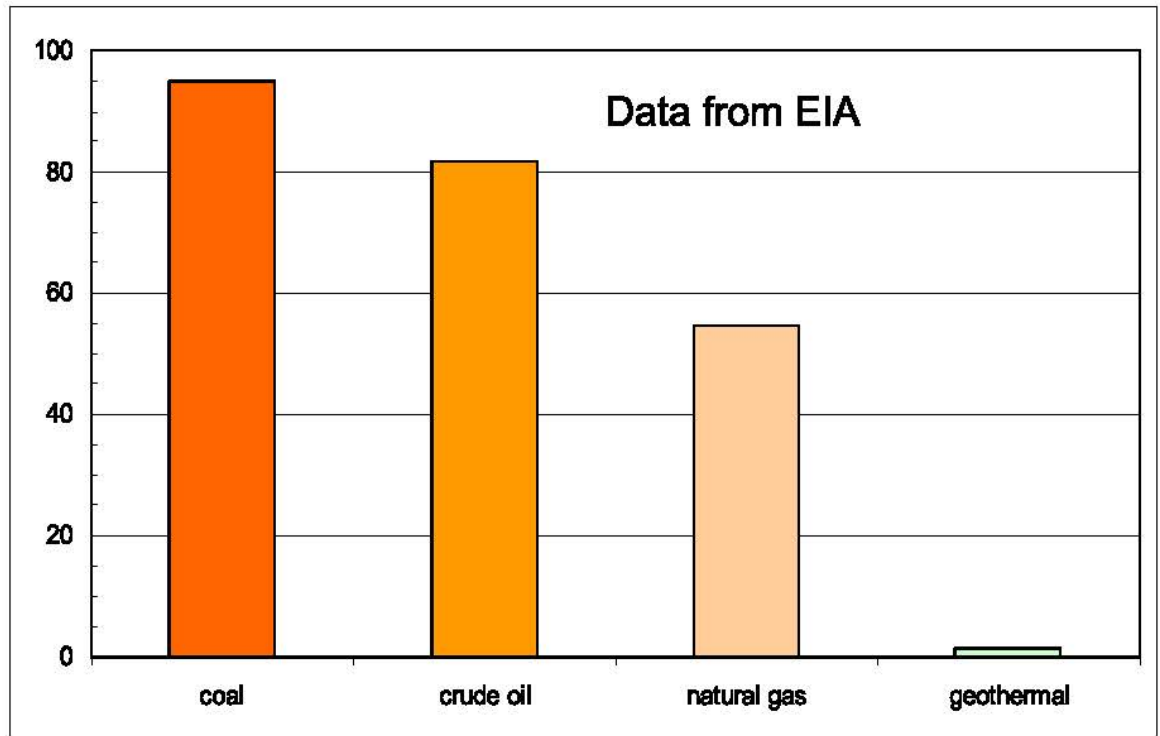
Status of Geothermal Energy

- 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
  - Magmatic or Amagmatic
  - 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		New USGS assessment
Temperature >150°C and Depth <3 km for electric power production	⟺	Temperature >90°C and Depth up to 6 km for electric power production (~75°C in Alaska)
52 identified high temperature systems	⟺	241 identified moderate and high temperature systems
Identified systems poorly characterized	⟺	Abundant exploration and production data
Idealized reservoir performance	⟺	Improved models for reservoir performance
Rough estimates of undiscovered resources	⟺	Better quantitative estimates of undiscovered resources
EGS mentioned but not estimated	⟺	Enhanced Geothermal Systems included
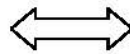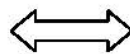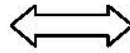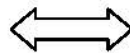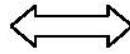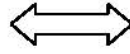
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Identified Geothermal Systems
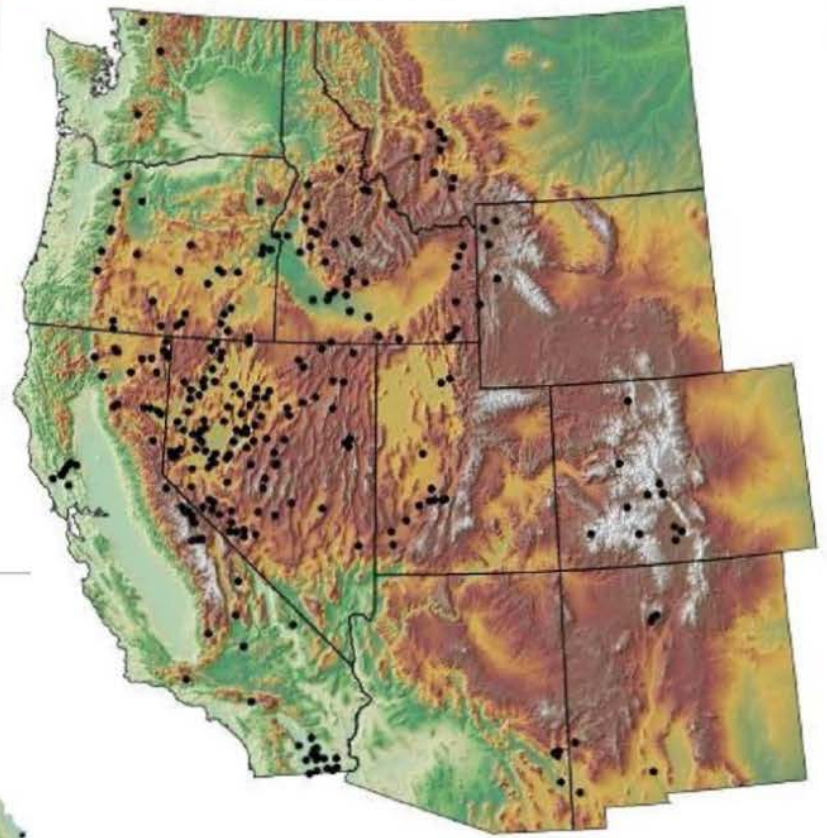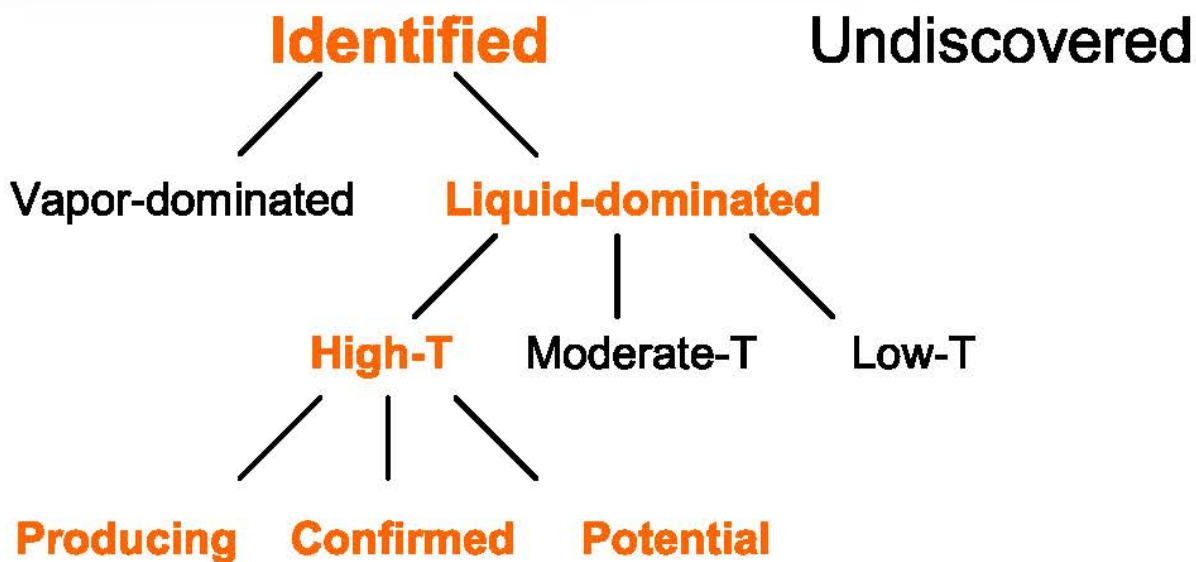
Geothermal Systems and Public Lands

Geothermal Systems in Alaska

Federal Lands on the Hawaiian Islands

Geothermal Systems in the Western United States
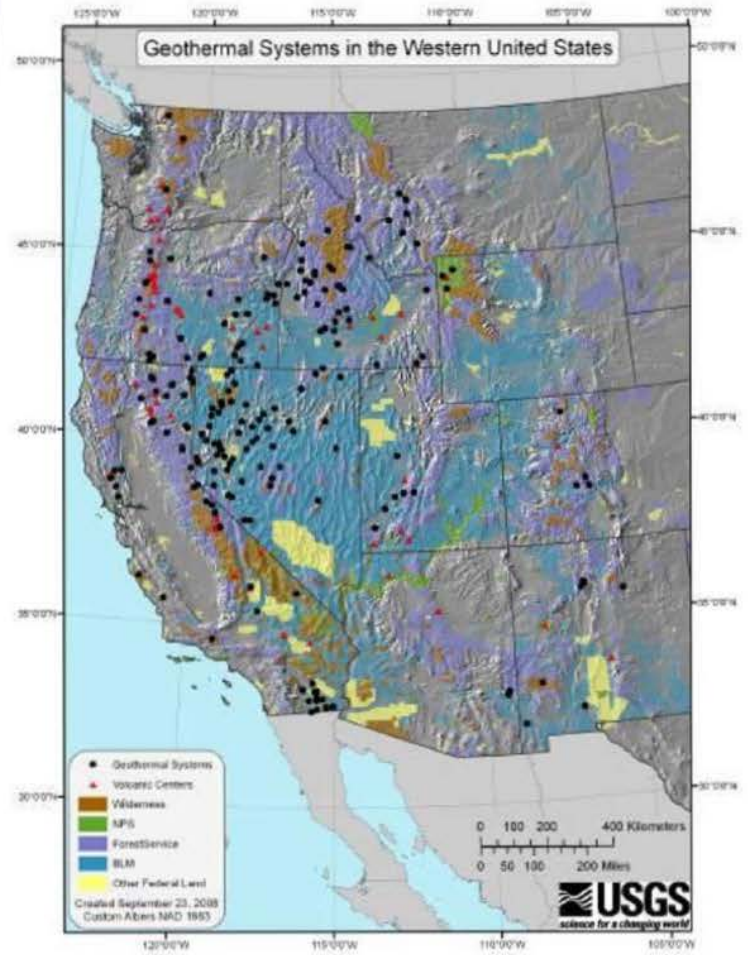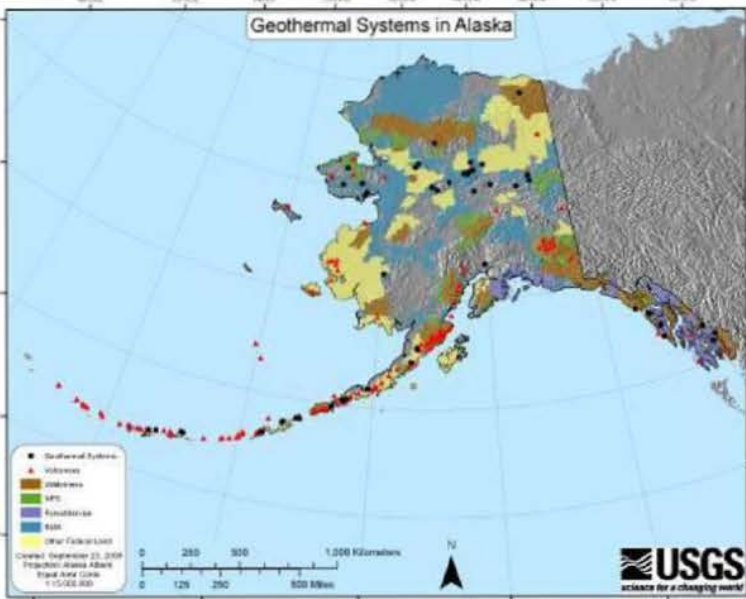
Geothermal Assessment Concepts

Reserves – Geothermal energy that can be extracted legally and economically.

Resources – Geothermal energy that is technically recoverable and can be added to Reserves at some future time.

GEOTHERMAL RESOURCES
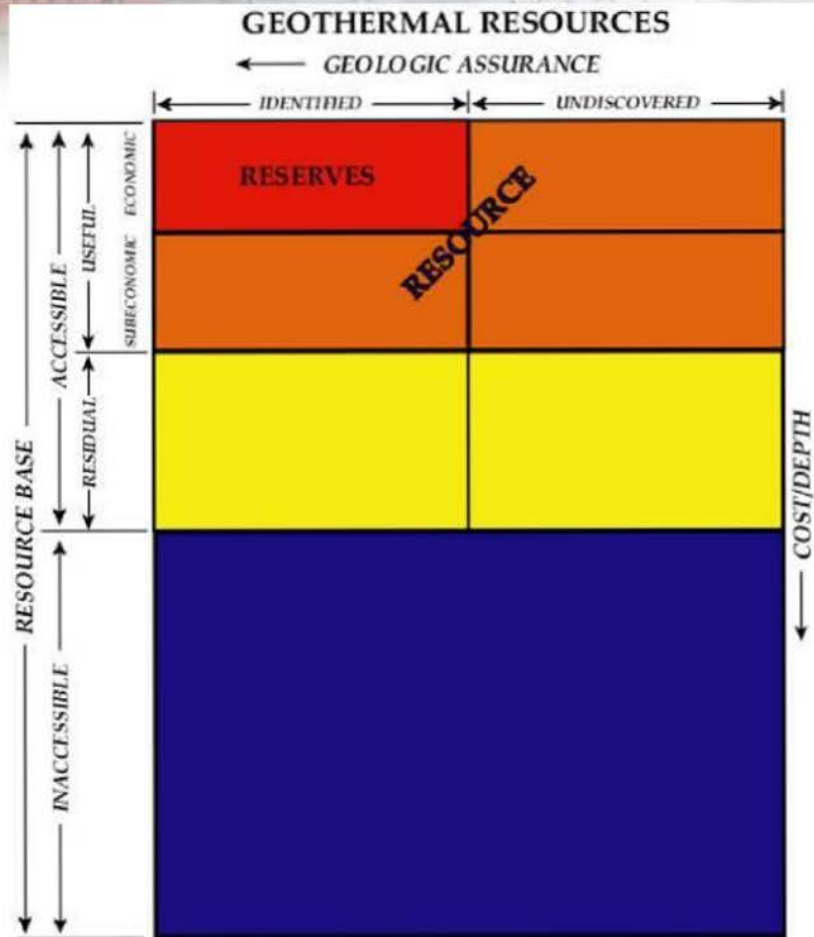
Geothermal Resource Categories

Identified   Undiscovered

Vapor-dominated   **Liquid-dominated**

High-T   Moderate-T   Low-T

Producing   Confirmed   Potential

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
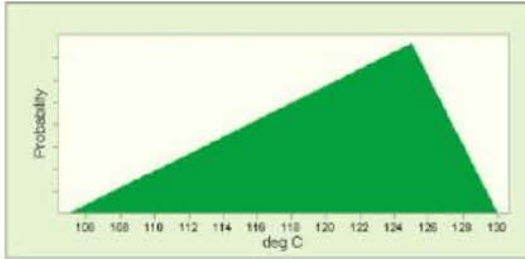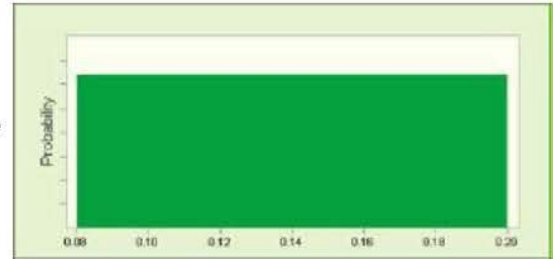
Reservoir Volume

Recovery Factor
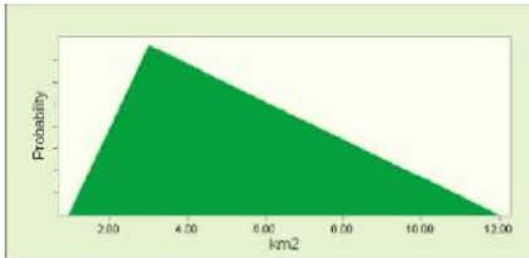
Reservoir Thermal Energy

Electric Power

~80% of systems = 90 to 150°C
~20% >150°C
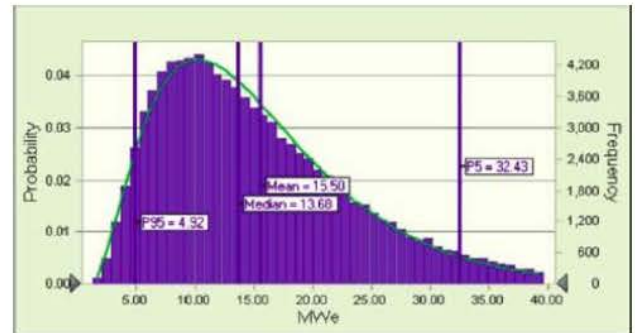
Volume Distribution of Identified Systems

Reservoir volumes of most identified geothermal systems <5 km³

2 systems →

Identified Systems Potential –

Mean = 9057 MWe
F95 = 3675 MWe
F5 = 16457 MWe
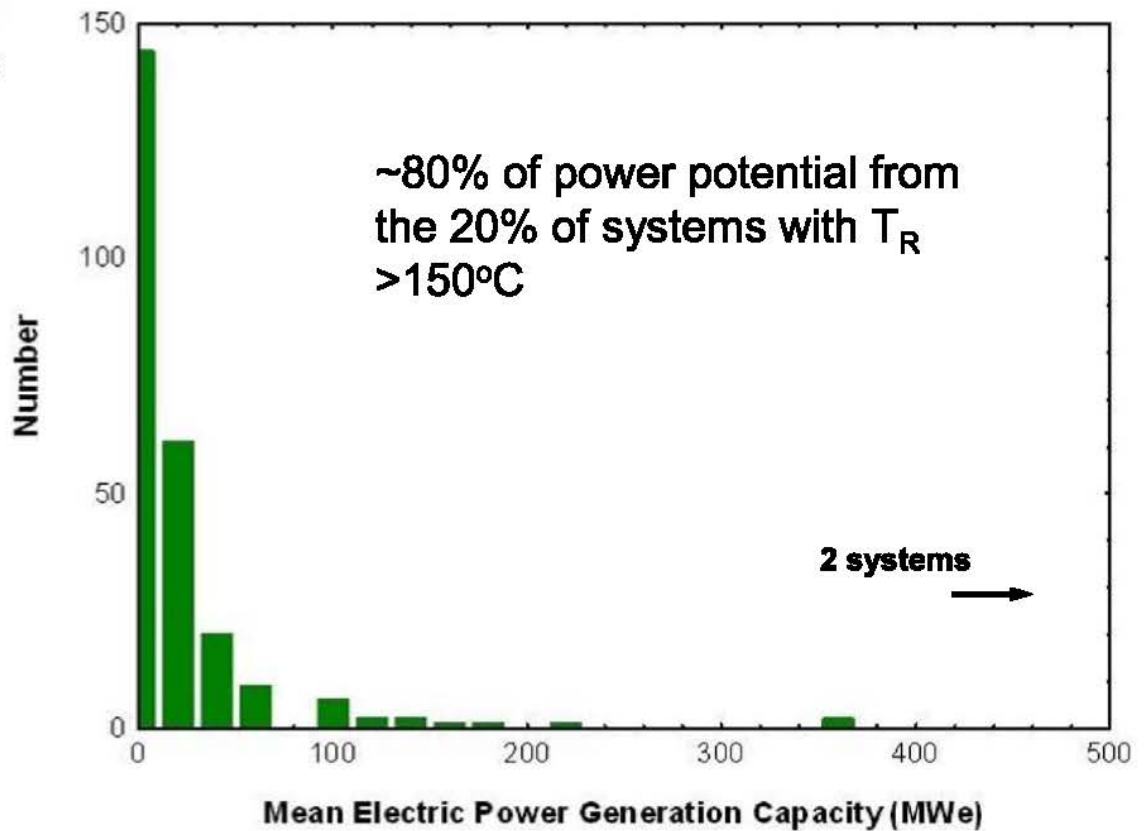
~80% of power potential from the 20% of systems with T_R >150°C

2 systems →

Number (y-axis)

**Mean Electric Power Generation Capacity (MWe)** (x-axis)

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Undiscovered Resources – Geothermal Favorability Maps

Warmer colors represent high probability for the presence of geothermal systems

Geothermal Favorability

High

Low
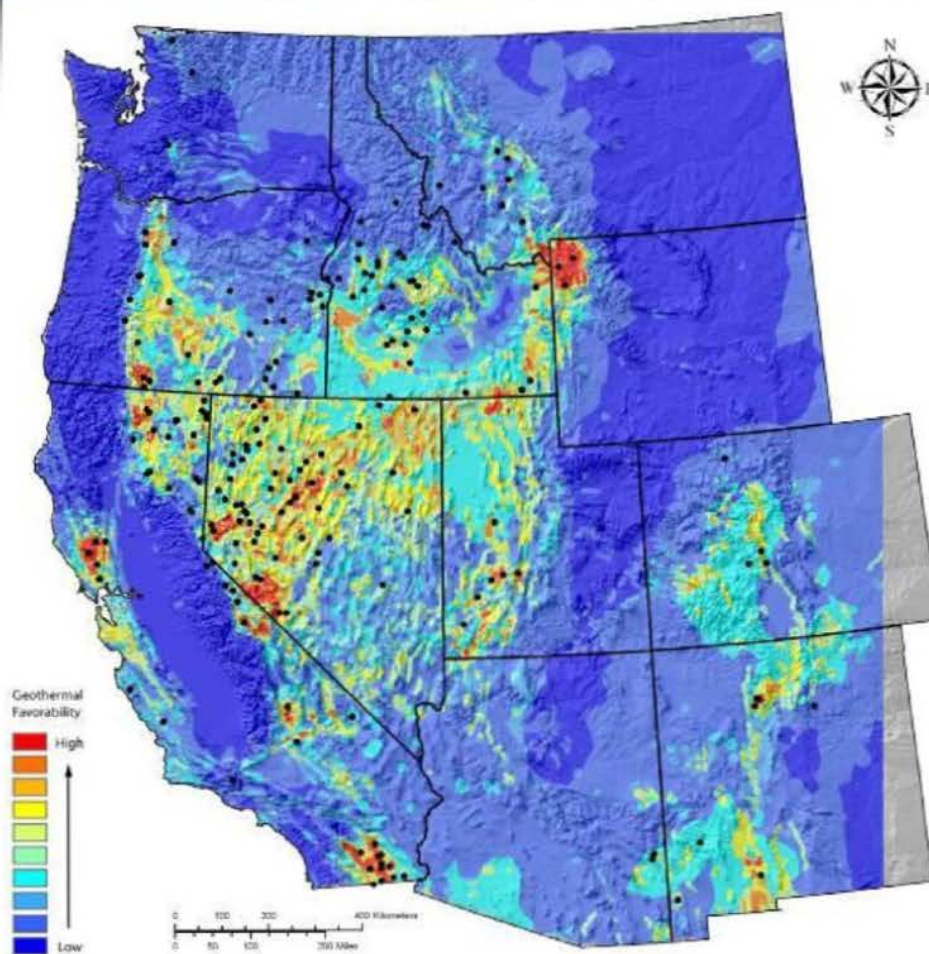
Undiscovered Resources – Effect of Closed Public Lands

Undiscovered
Resources –
Mean = 30,033 MWe
F95 = 7917 MWe
F5 = 73,286 MWe
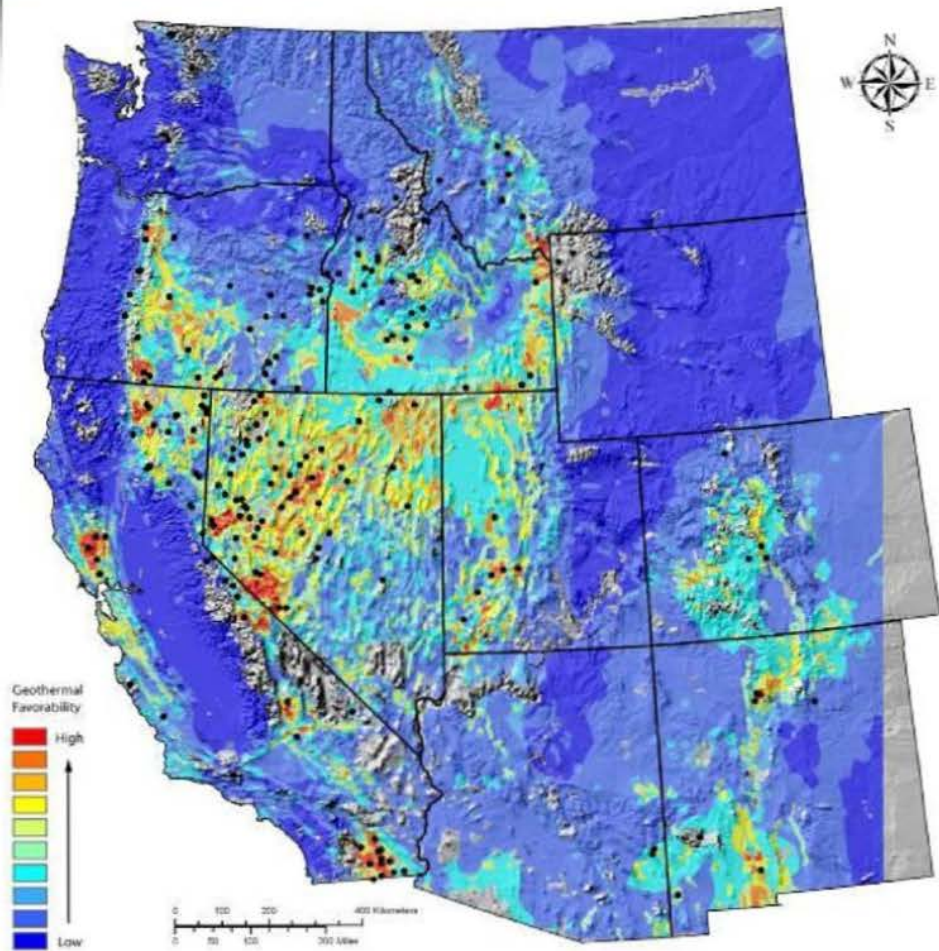
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Enhanced Geothermal Systems (EGS)

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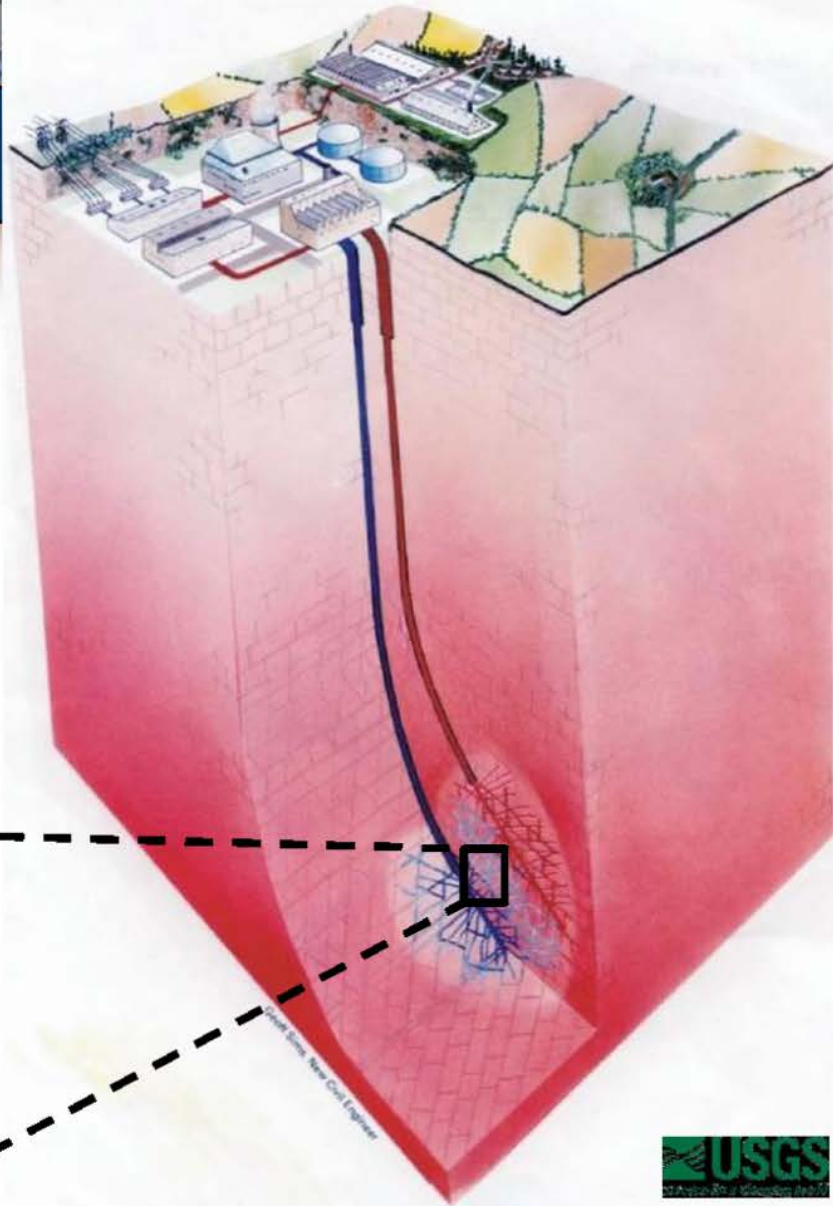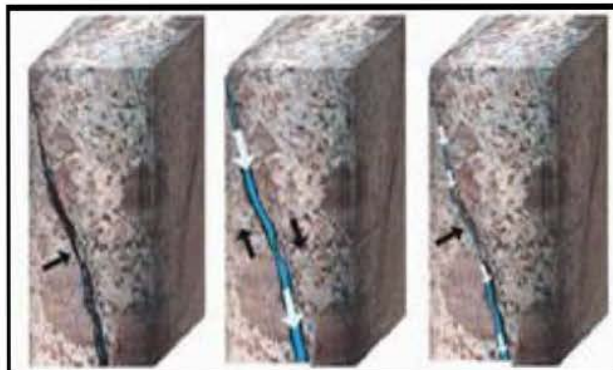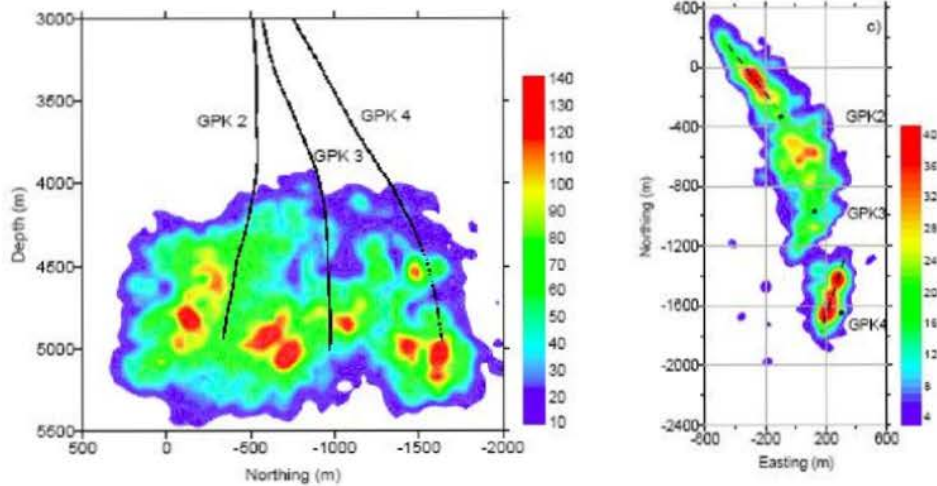
Enhanced Geothermal Systems

- Large regions of the western US with temperatures above 200 °C 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
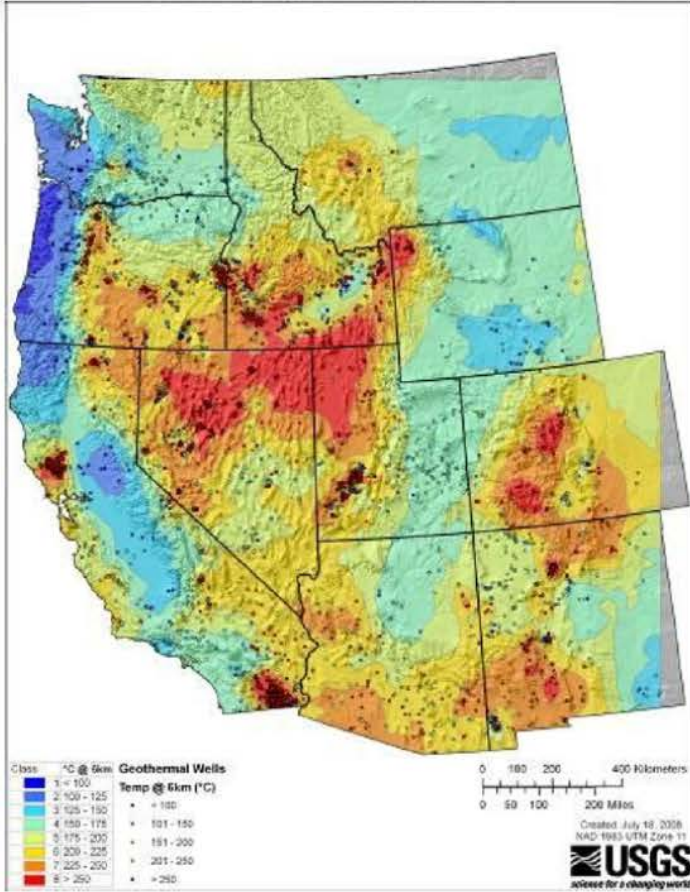
Maps of microearthquake density from reservoir stimulation

Soultz-sous-Forets, France
Stimulated Volume ~6-8 km^3
Temperature ~200°C
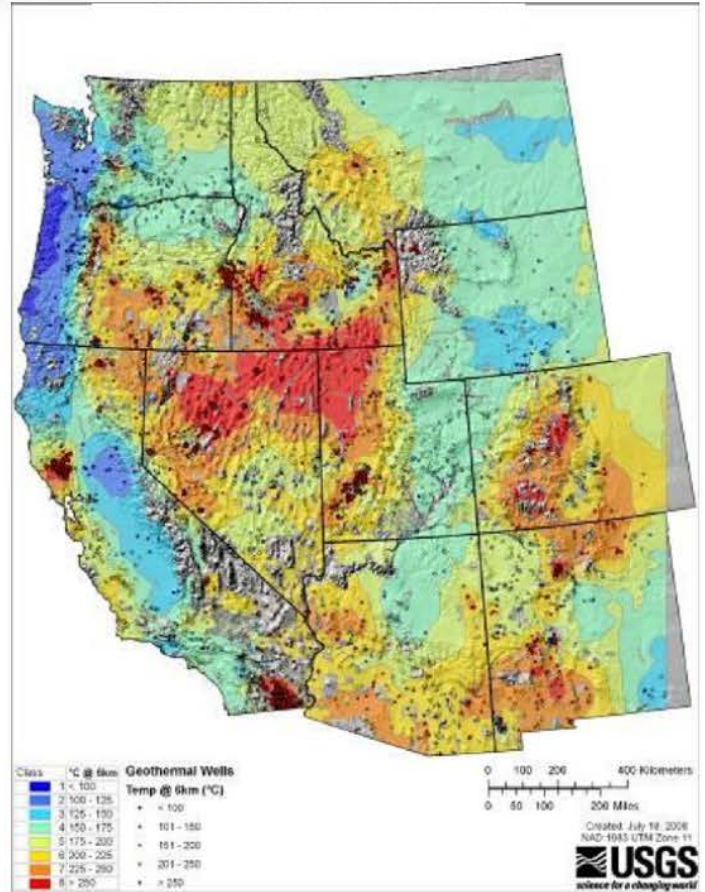Potential Generation ~1.5MWe

(Tischner et al., 2007)

Enhanced Geothermal Systems – USGS Deep Temperatures
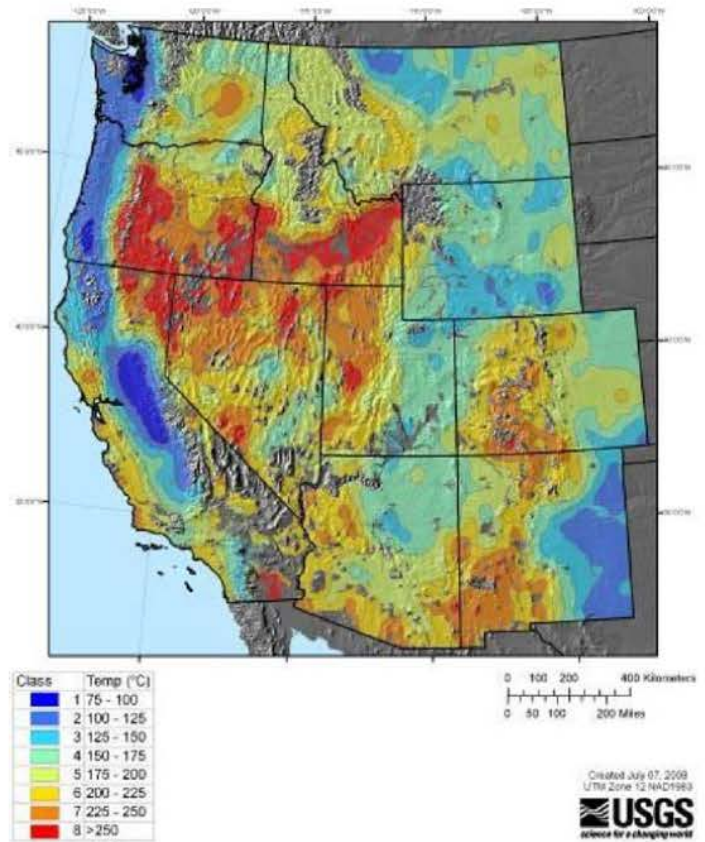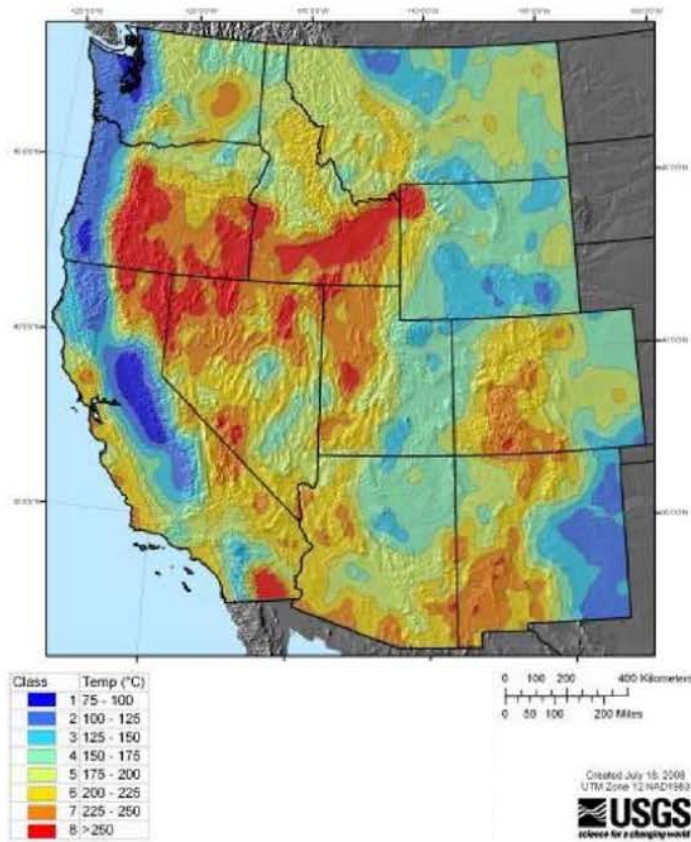
Temperature contours

Temperature contours w/o closed public lands

Enhanced Geothermal Systems – SMU Deep Temperatures

Temperature contours

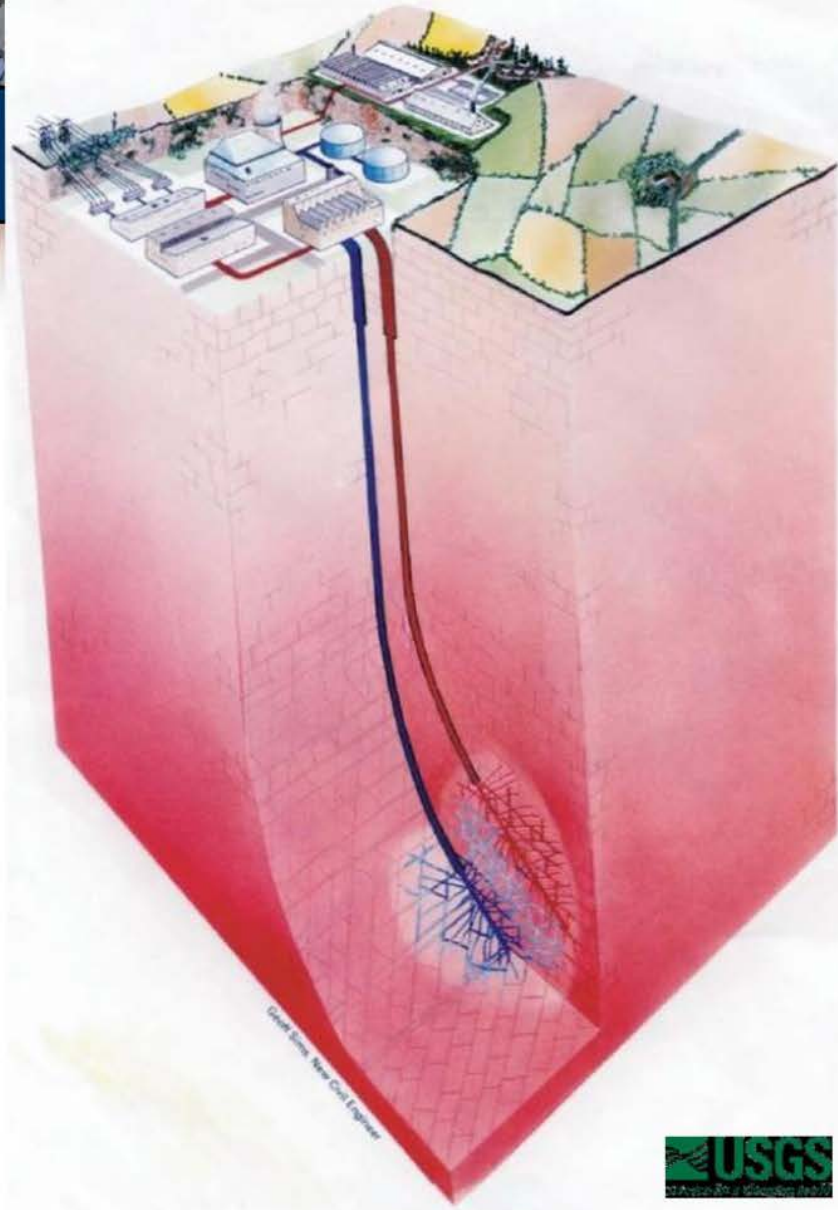Temperature contours w/o closed public lands

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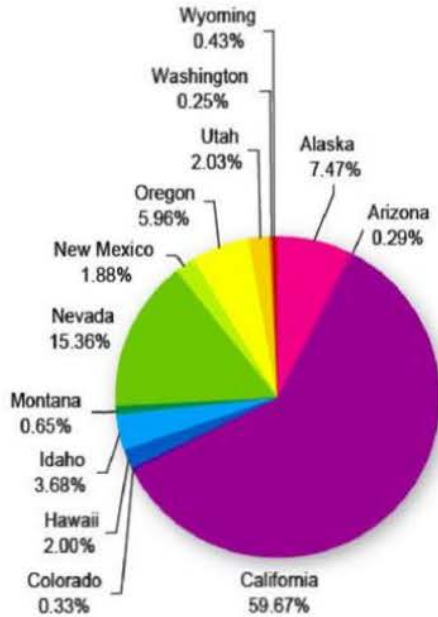Mean = 517,800 MWe
F95 = 345,100 MWe
F5 = 727,900 MWe

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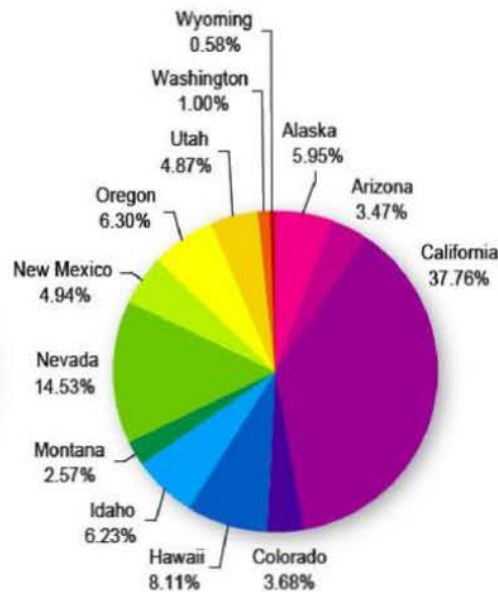DOE-sponsored studies, despite
differences in approach.

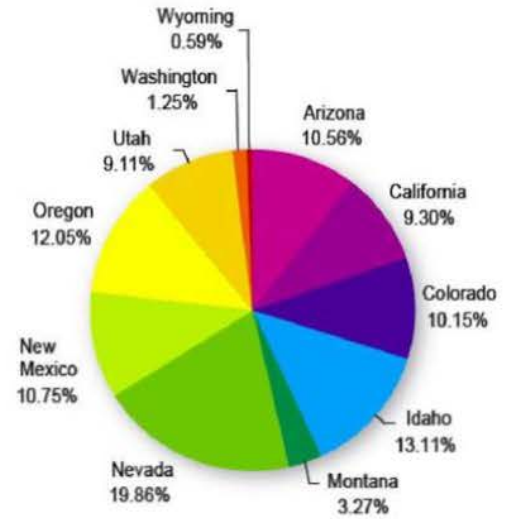# Distribution of Geothermal Potential

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.

• This new assessment is the first comprehensive national geothermal resource assessment since 1978 (USGS Circular 790).

Acknowledgements

USGS Energy Resources Program

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http://energy.usgs.gov/