SAND2005-7894P

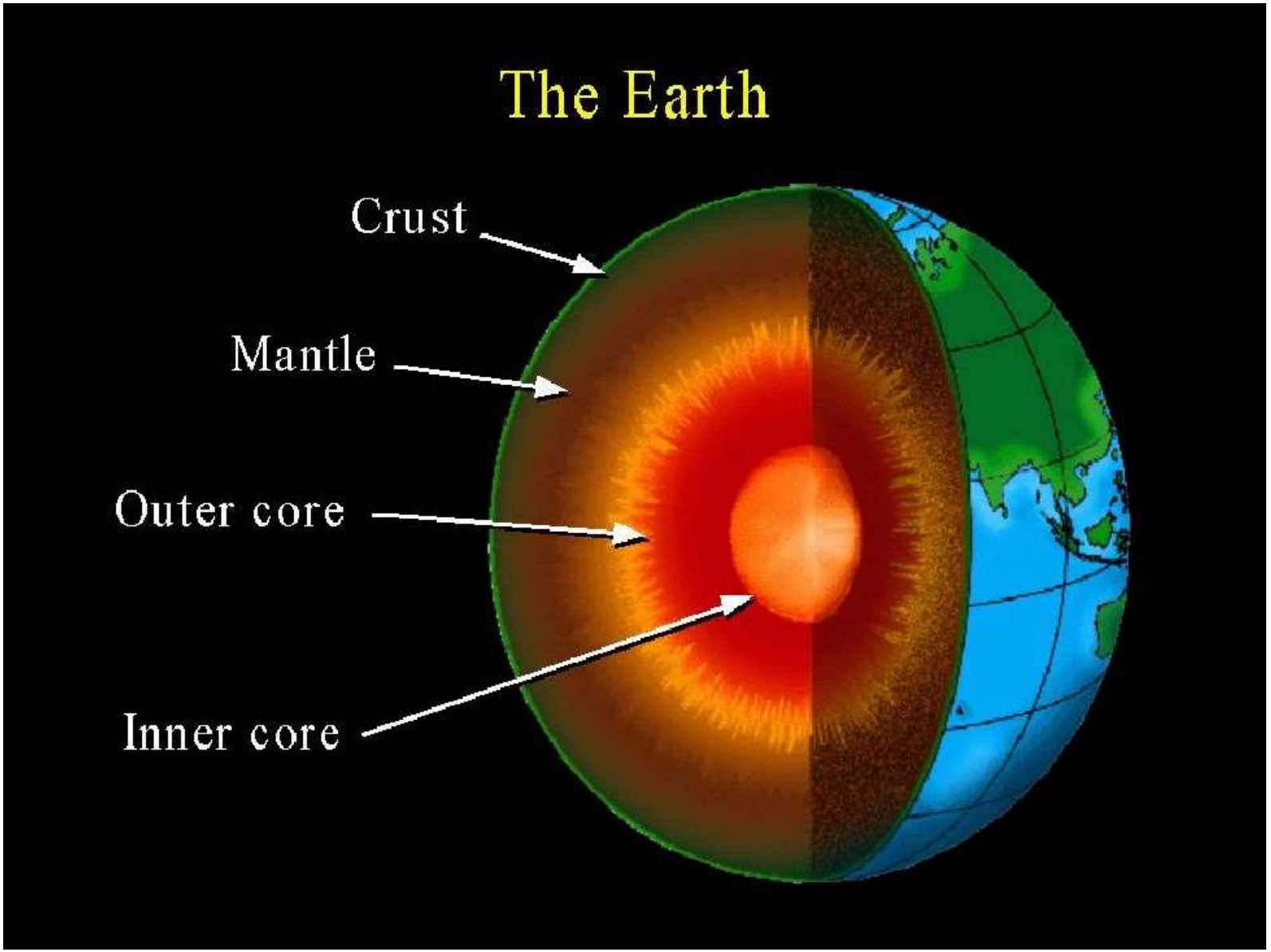
Why Geothermal?

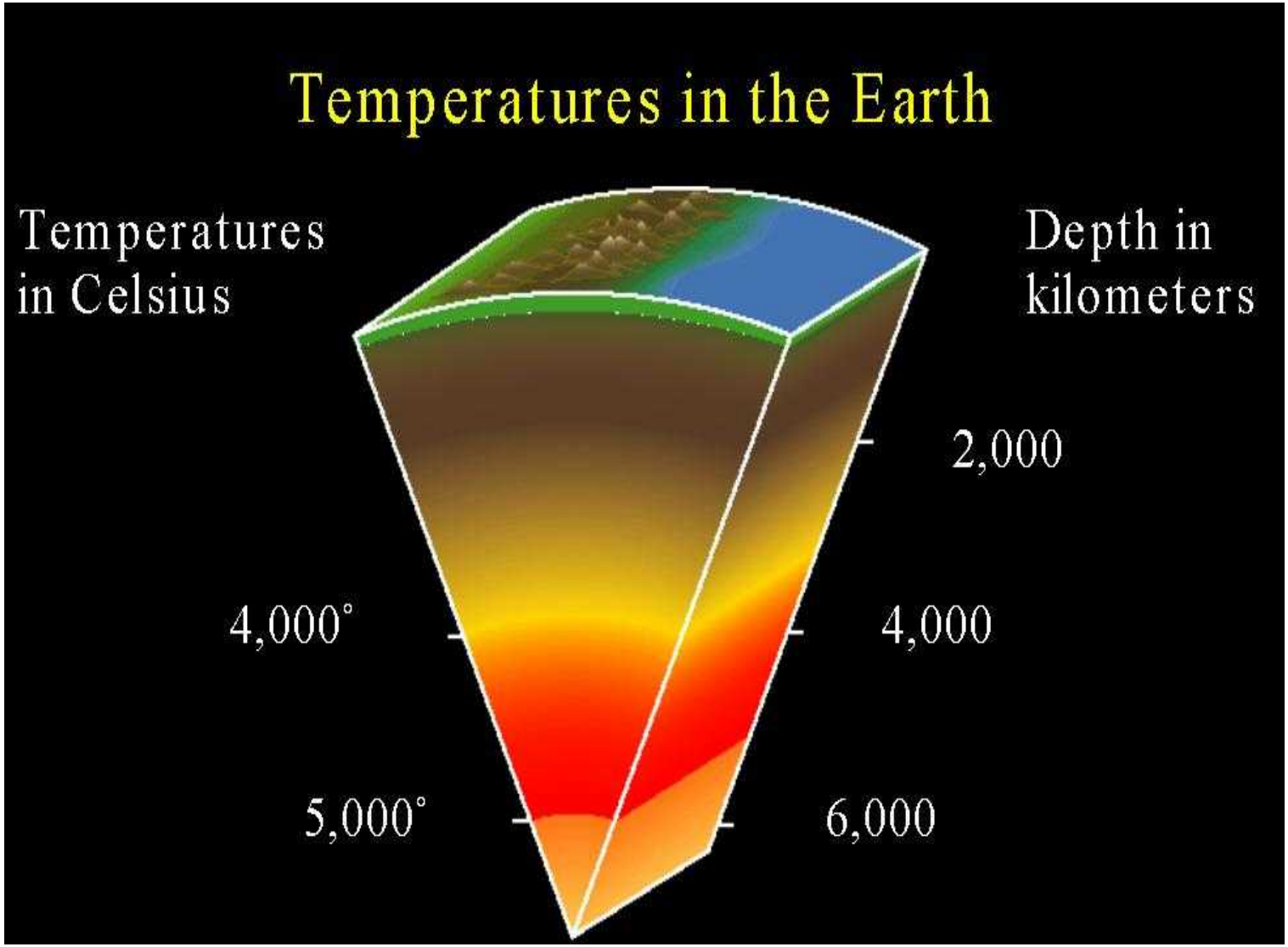
Why Geothermal?

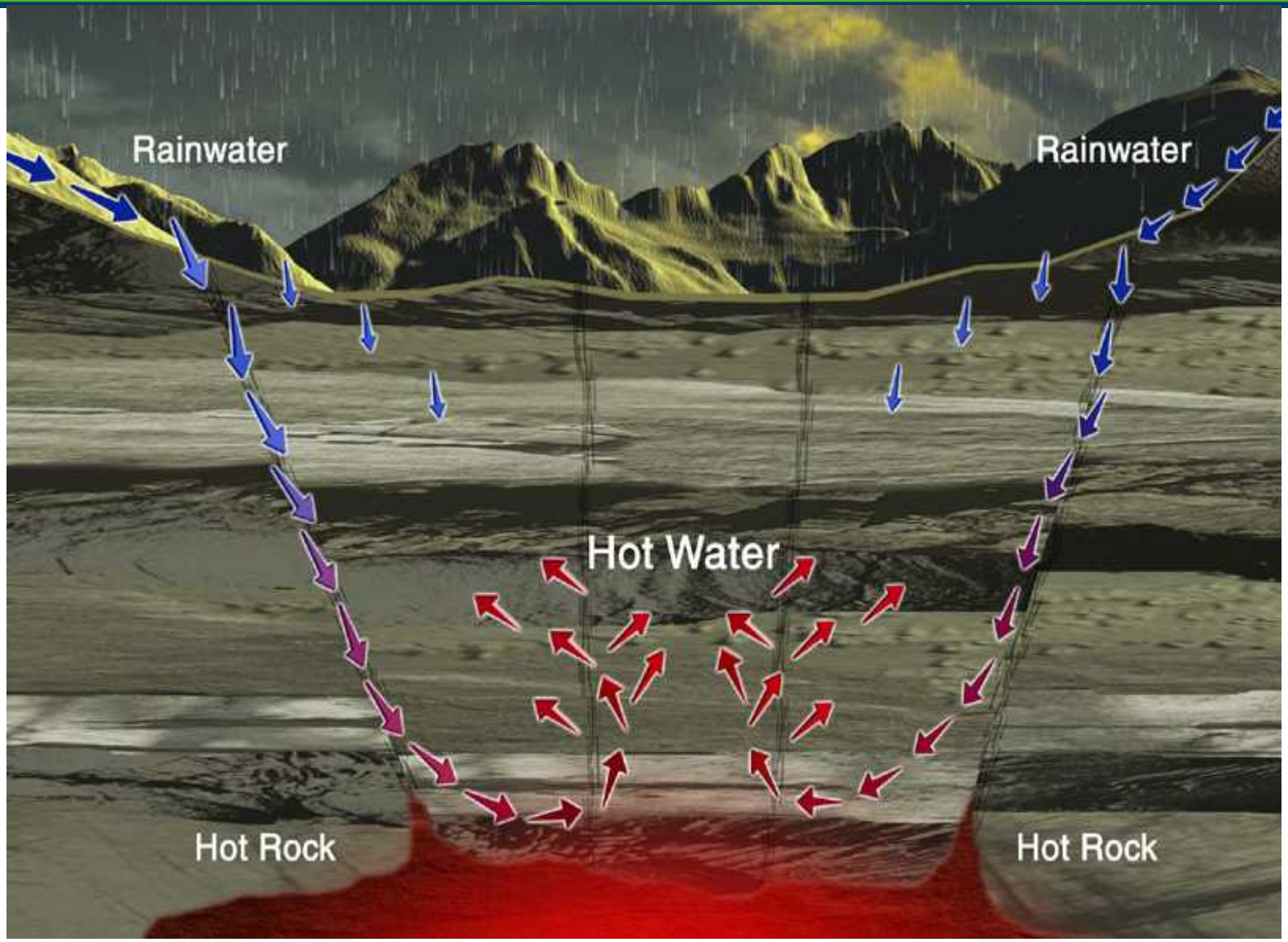
- Energy Security
- Electric Restructuring
- Clean Air & Water
- Climate Change Advantage
- Economic Competitiveness

Basic Geothermal Concepts

- Source of geothermal energy
- Temperatures in the Earth by depth
- Geophysical interactions


The Earth
Crust
Mantle
Outer core
Inner core


Temperatures in the Earth
Temperatures in Celsius
Depth in kilometers
2,000
4,000°
4,000
5,000°
6,000



Courtesy of Geothermal Education Association

Geothermal Energy is Heat from the Earth

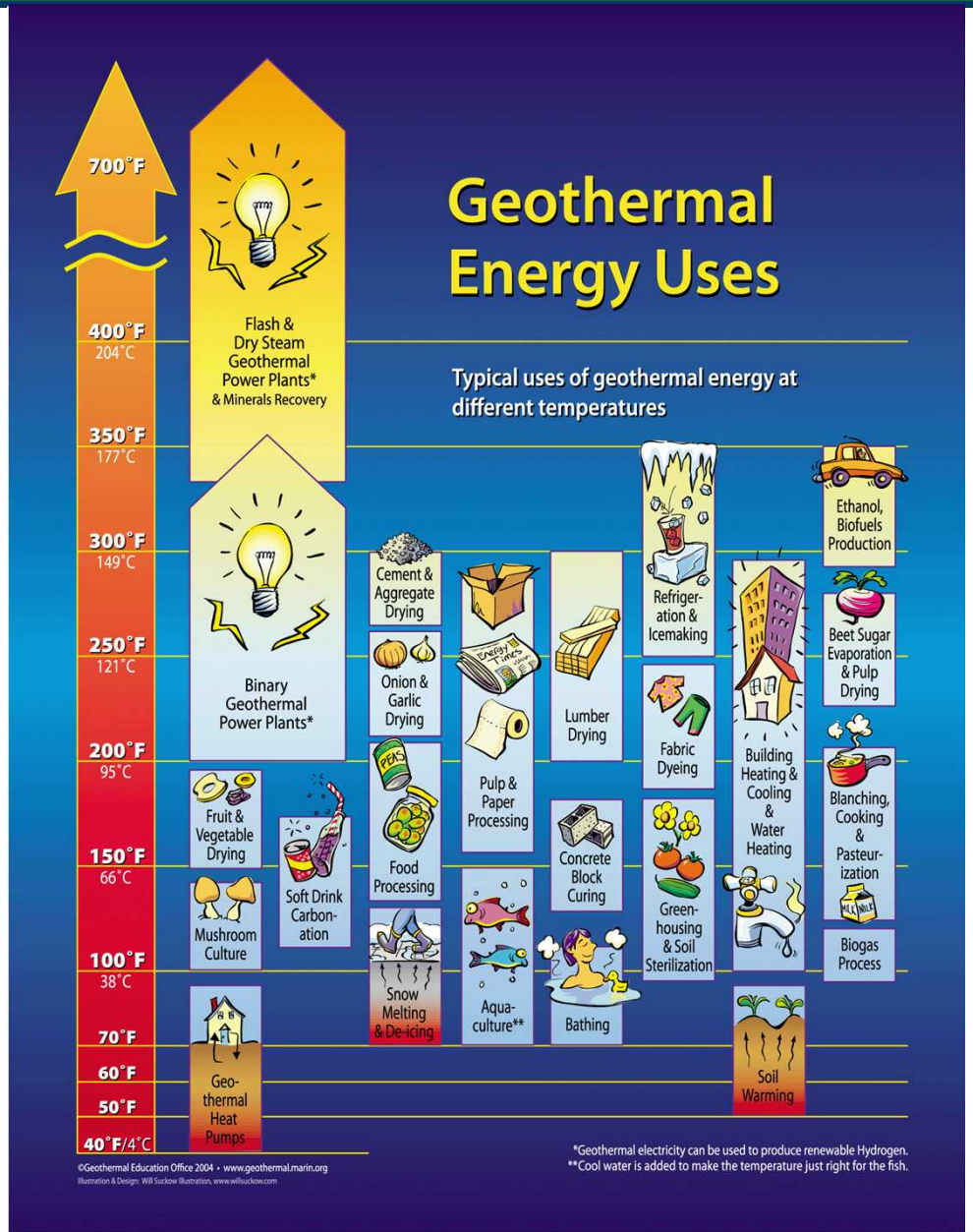
How Geothermal Energy is Used:

- Electricity Generation
- Direct Thermal Use
- Geothermal Heat Pumps.

Power

Direct Use

Geo Heat Pump

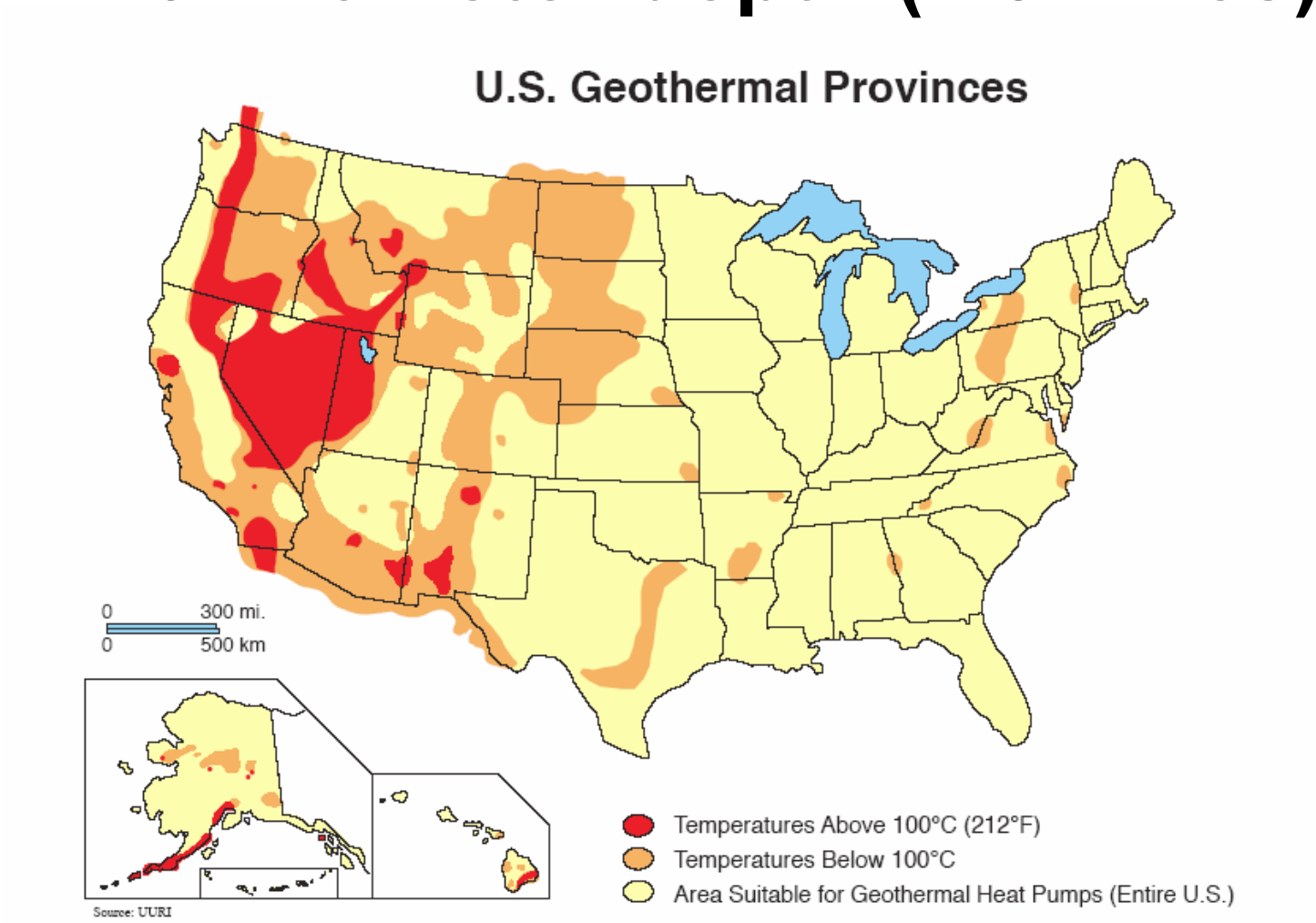

Geothermal Energy Uses
Typical uses of geothermal energy at different temperatures
700°F
400°F
204°C
350°F
177°C
300°F
149°C
250°F
121°C
200°F
95°C
150°F
66°C
100°F
38°C
70°F
60°F
50°F
40°F/4°C
Flash & Dry Steam Geothermal Power Plants* & Minerals Recovery
Binary Geothermal Power Plants*
Fruit & Vegetable Drying
Soft Drink Carbon-ation
Mushroom Culture
Geo-thermal Heat Pumps
Cement & Aggregate Drying
Onion & Garlic Drying
Food Processing
Snow Melting & De-icing
Pulp & Paper Processing
Aqua-culture**
Lumber Drying
Concrete Block Curing
Bathing
Refriger-ation & Icemaking
Fabric Dyeing
Green-housing & Soil Sterilization
Building Heating & Cooling & Water Heating
Soil Warming
Ethanol, Biofuels Production
Beet Sugar Evaporation & Pulp Drying
Blanching, Cooking & Pasteur-ization
Biogas Process
*Geothermal electricity can be used to produce renewable Hydrogen.
**Cool water is added to make the temperature just right for the fish.
©Geothermal Education Office 2004 • www.geothermal.marin.org
Illustration & Design: Will Suckow Illustration, www.willsuckow.com

Vast Potential

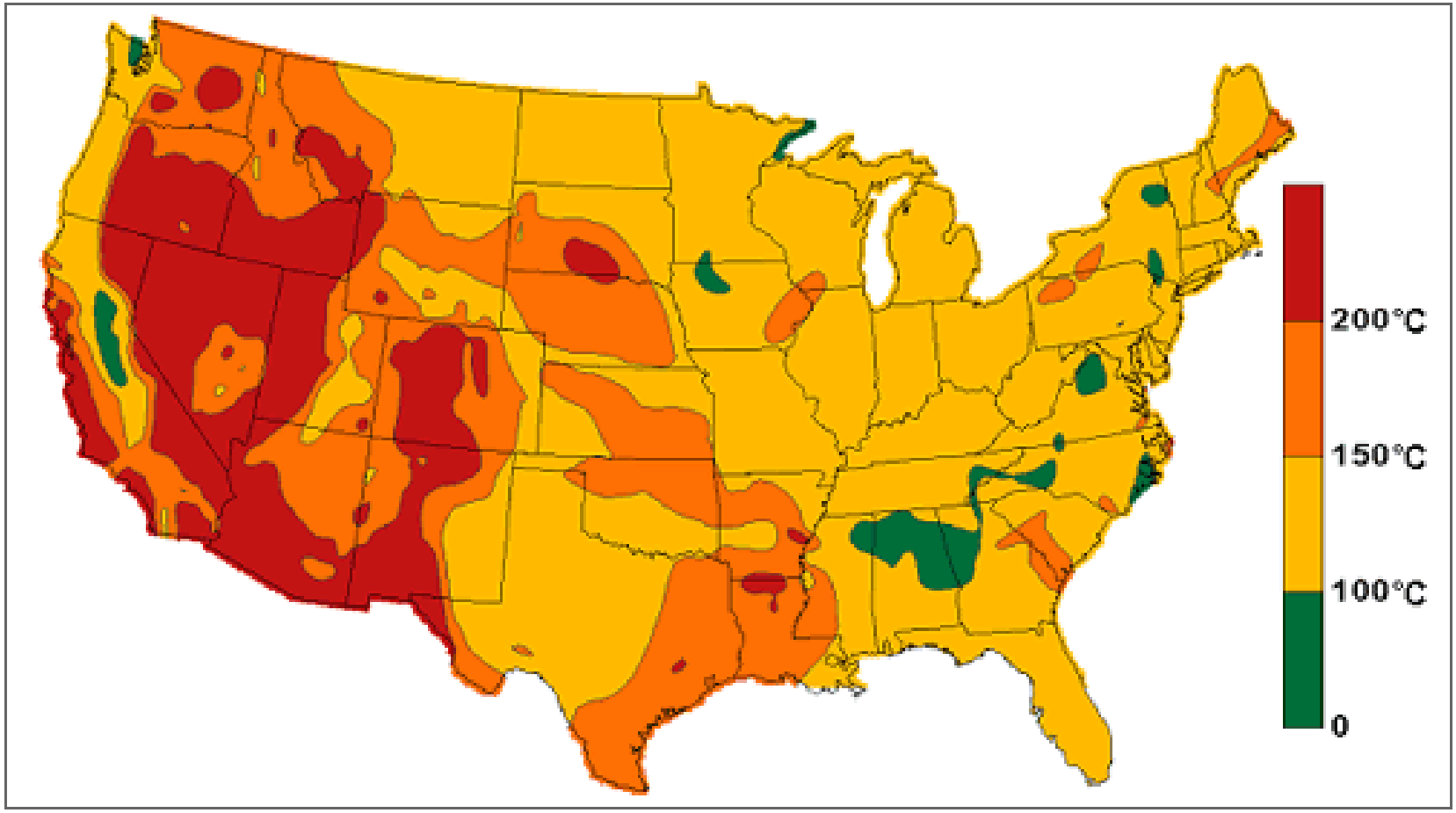
The energy content of domestic geothermal resources to a depth of 3 km is estimated to be 3 million quads, **equivalent to a 30,000-year supply of energy for the United States**.

Source: Assessment of Geothermal Resources of the United States---1978, Muffler, L.J.P. (ed.), U.S. Geological Survey Circular 790, 1979.

Geothermal Potential
3 kilometer depth (1.9 miles)

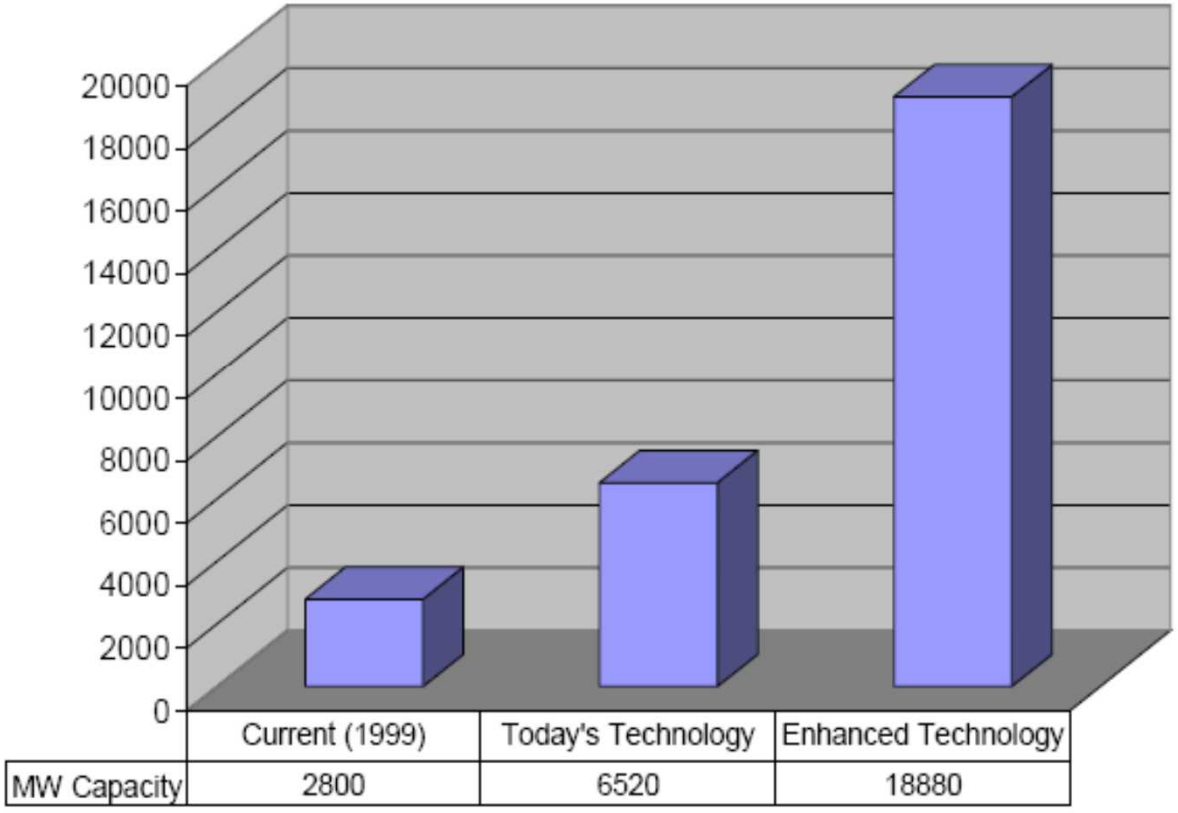


Geothermal Potential at 6 kilometer (3.8 mile) depth



Source: U.S. DOE

U.S. Geothermal Potential



	Current (1999)	Today's Technology	Enhanced Technology
MW Capacity	2800	6520	18880

Source: *Geothermal Energy: The Potential for Clean Power from the Earth*, Geothermal Energy Association, www.geo-energy.org/PotentialReport.htm

New Geothermal Power Plants

New plants are being pursued in:

- **Alaska**
- **Arizona**
- **California**
- **Hawaii**
- **Idaho**
- **Nevada**
- **New Mexico**
- **Oregon**
- **Utah**

Source: Utilipoint® Issue Alert, *The Earth as a Power Source*, May 5, 2005

Significant Power Production

Geothermal plants produce 6% of California's electricity (12.2 million MWh in 2001)

Geothermal provides about 30% of the electricity needs of the Philippines.

This hybrid binary/flash power plant provides about 25% of electricity demand on the Big Island of Hawaii

Great Value for Investment

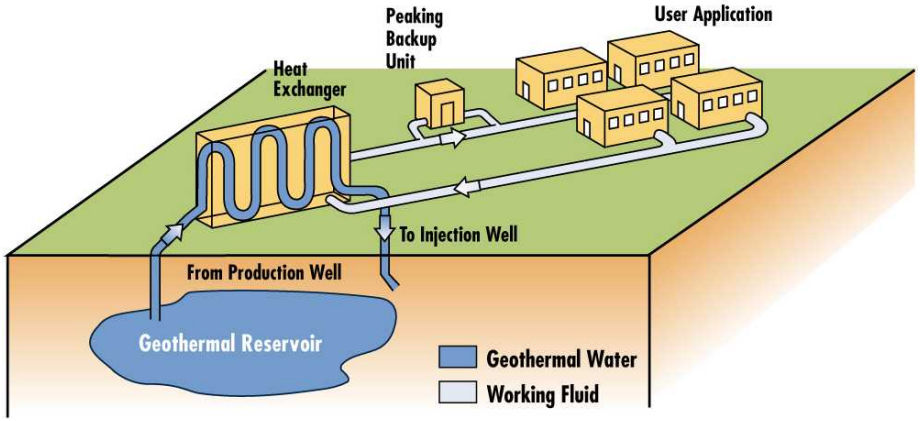
- Returns over $41 million annually to the U.S. Treasury in royalty and production payments for geothermal development on federal land.
- The retail value of electricity generated via geothermal plants exceeds $1 billion per year.
- Six R&D 100 Awards in five years.

Direct Use

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

Alligators in Colorado

More Direct Uses



District Heating

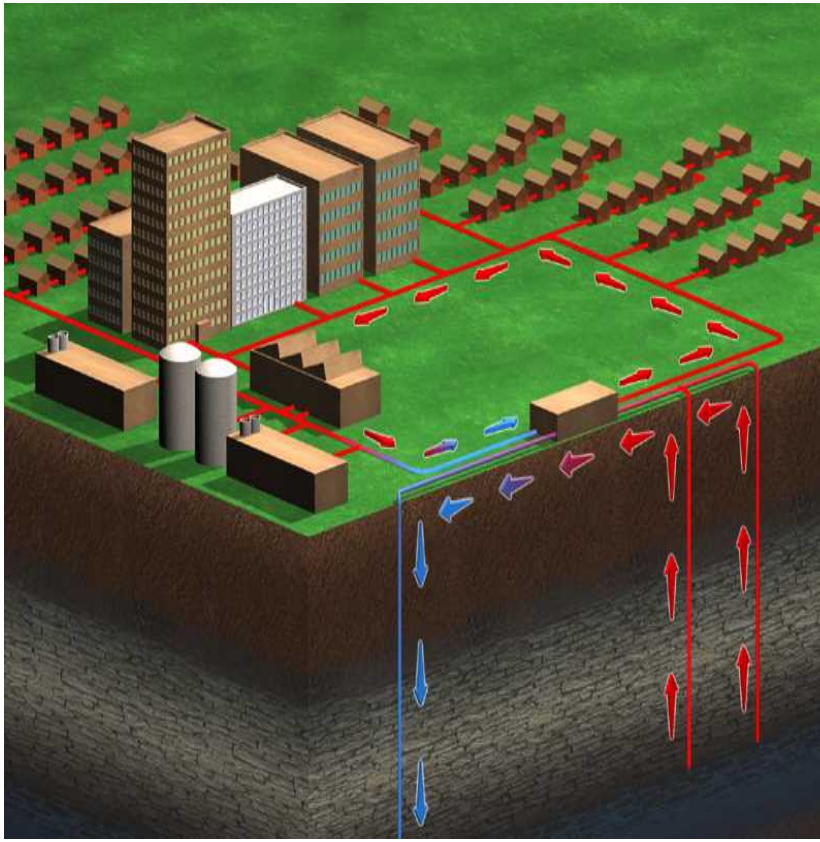
Greenhouses

Space Heating

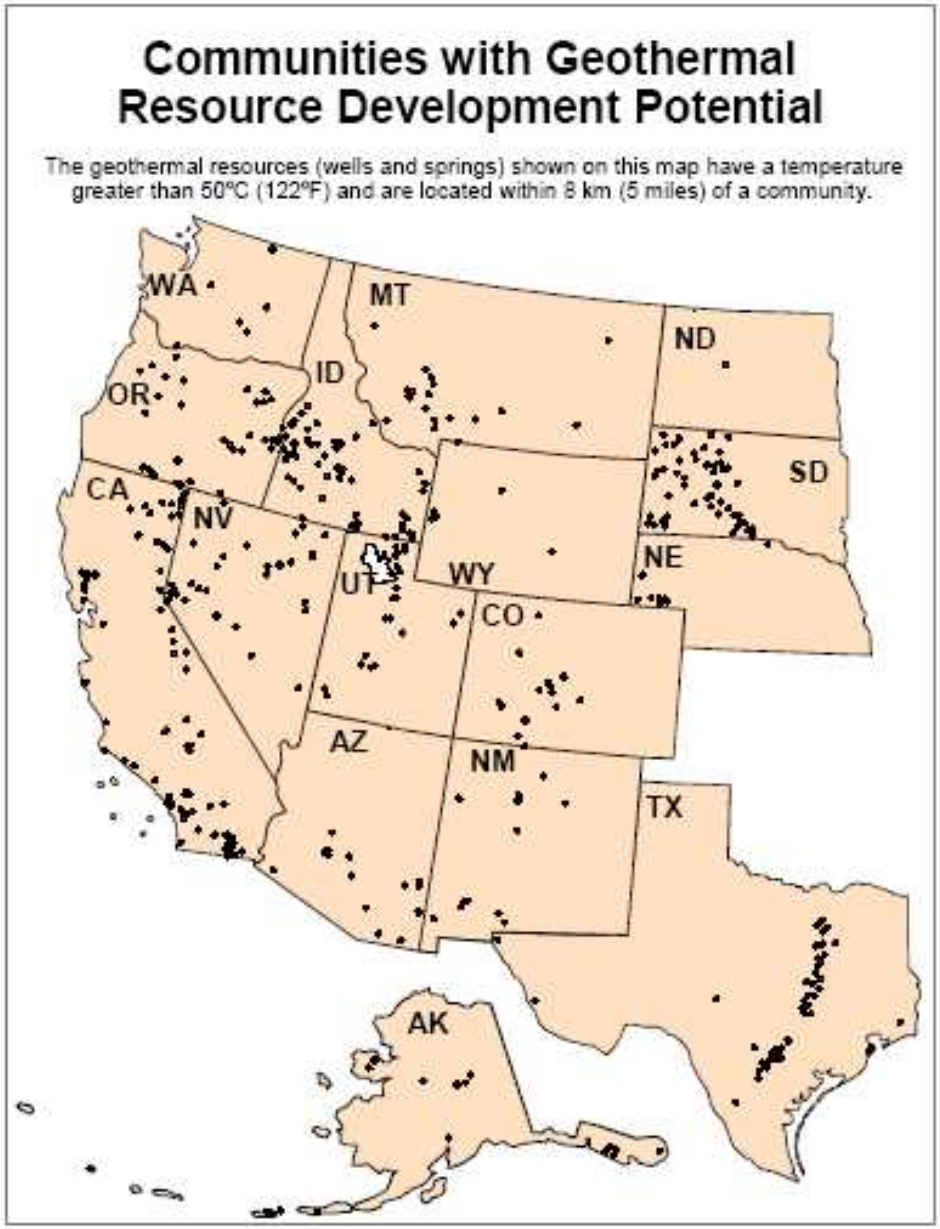
Snow Melting

District Heating in Western U.S.

- There are 18 geothermal 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.



A recent study identified **271** cities and communities in the 10 western states that could potentially utilize geothermal energy for district heating and other applications.



Source: Geo-Heat Center, Oregon Institute of Technology.

Geothermal Heat Pumps

Heating Mode

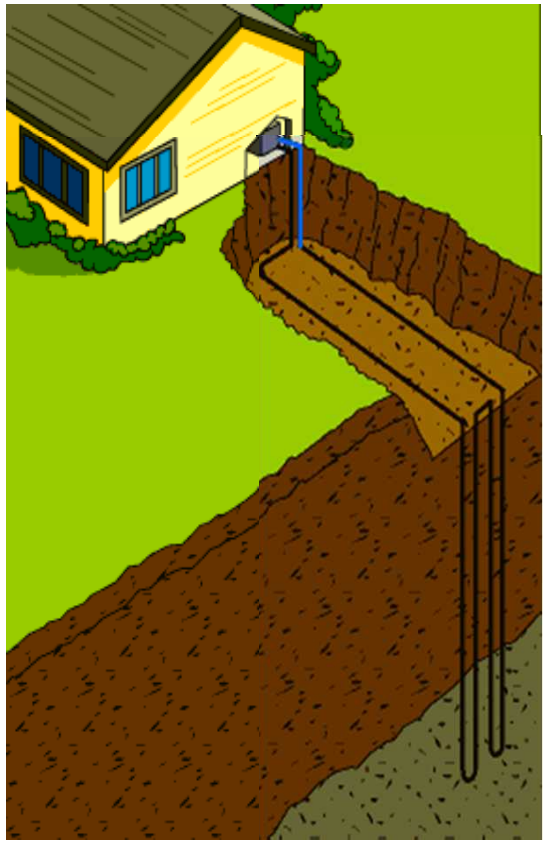


Illustration developed by NREL

Geothermal heat pumps use the stable temperatures of the ground (often vertical boreholes typically are 100 to 400 feet deep) as a heat source to warm buildings in winter and as a heat sink to cool them in summer. Also called ground-source heat pumps or Geoexchange units.

Geothermal Heat Pumps

Cooling Mode

Illustration developed by NREL

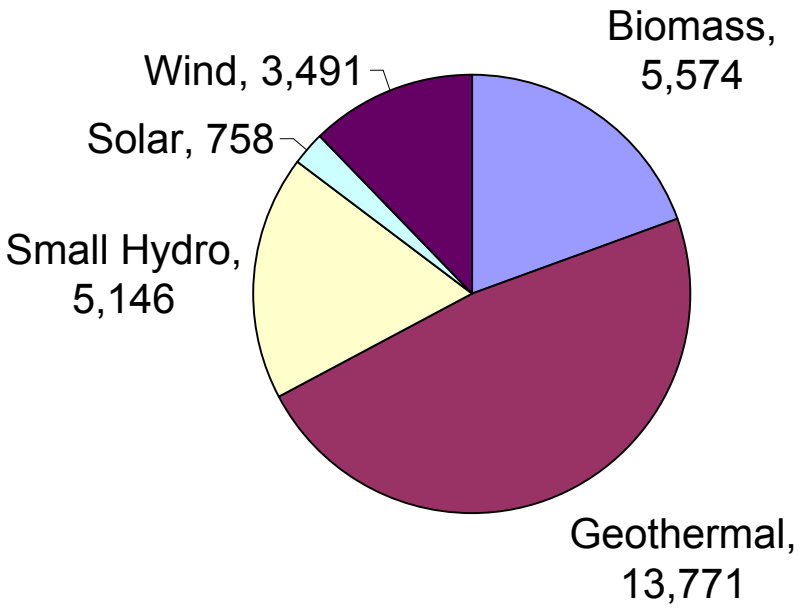
Geothermal Energy Use in the U.S.

- 2,750 megawatts of installed electrical capacity, supplying 4 million people in western U.S. and Hawaii
- 600 thermal megawatts of direct use for heating*
- 7,500 thermal megawatts geothermal heat pumps, about 750,000 in use today.*
- **Total Contribution = 10,850 megawatts.**

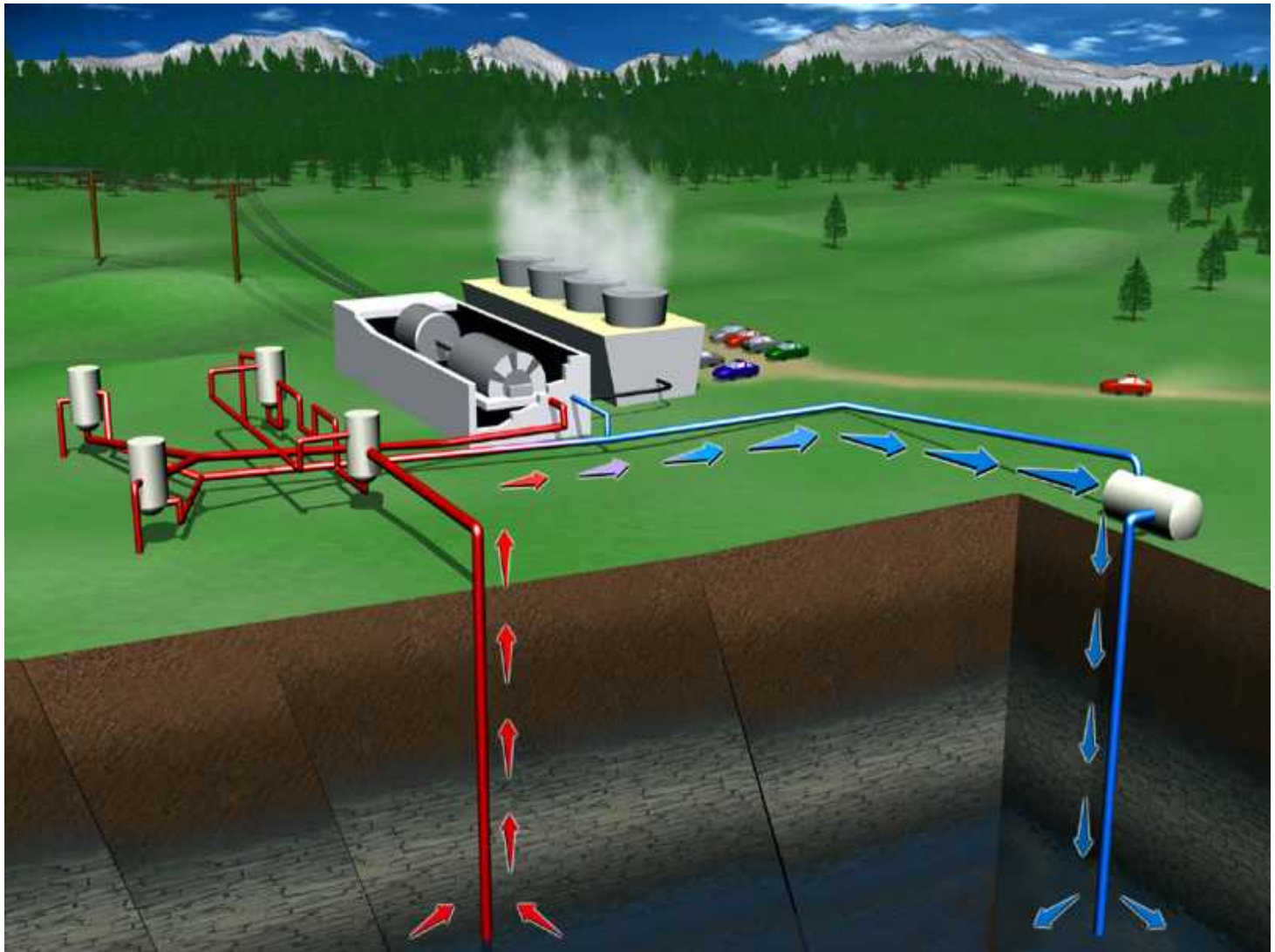
* Thermal megawatts do not equal electric megawatts. However, many direct use and geothermal heat pump applications offset electrical power needs, as well as natural gas, propane, or diesel fuels.

Major Renewable Power Provider for California

Total GWh Renewable Energy Use in California

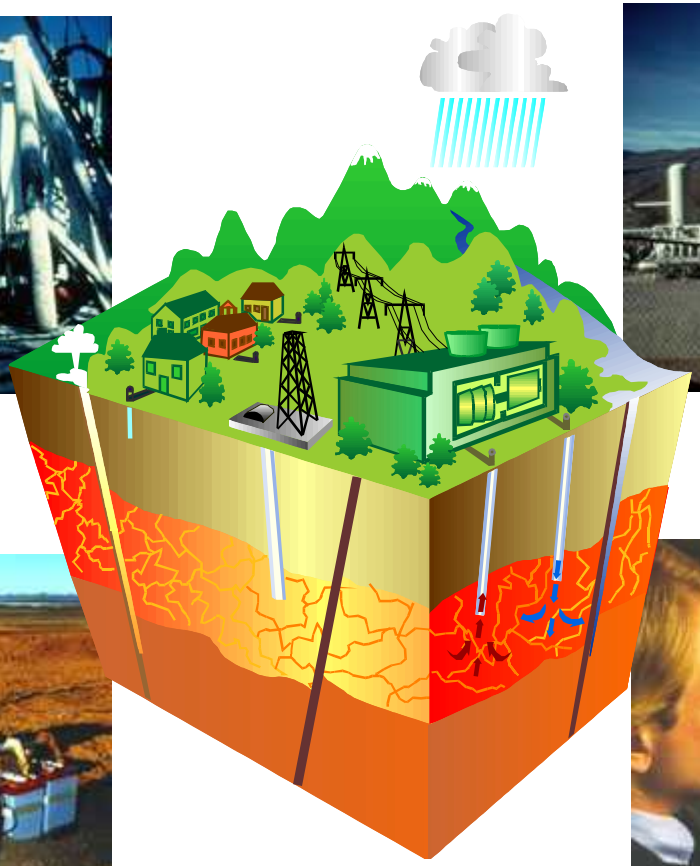


How Geothermal Power Works



Developing Geothermal Technology

Drilling



Energy Conversion

Exploration

Reservoir Technology

An Unusual Time!

- Highest Natural Gas Prices in History.
- Highest Coal Prices in 10 – 15 Years.
- Highest Oil Prices Since Gulf War.
- Highest Uranium Prices Since 1980s.
- All happening within past 3 months to 4 years.

Source: EIA *Monthly Energy Review* – July 2004, and EIA *Annual Energy Outlook with Projections to 2025*.

An Unusual Time!

"Markets for oil and natural gas have been subject to a degree of strain over the past year not experienced for a generation."

Alan Greenspan, Chairman, Federal Reserve

Source: Washington Post, April 6, 2005

Low & Uncertain Inventories: Nat. Gas

- More or less steady decline in production in spite of very high drilling numbers. Mature gas fields are overtaxed.
- Demand for natural gas in the U.S. has more than doubled over the past two decades, while supply has stagnated.
- Current rig count is near an all-time high, but wells are being depleted at an ever-increasing rate.
- Gaining access to public lands, where most of the promising gas fields are, has become increasingly difficult.

Source: EIA *Monthly Energy Review – July 2004*, and EIA *Annual Energy Outlook with Projections to 2025,* API at: www.naturalgasfacts.org/factsheets/overview.html.

Low & Uncertain Inventories: Nat. Gas

Factors shaping long-term demand for natural gas:

- 87 percent of new generating capacity is natural gas fired.
- Demand is growing because clean-burning natural gas is a preferred fuel due to its environmental benefits.
- The U.S. Department of Energy's Energy Information Administration forecasts that natural gas demand will grow by more than one-third by 2025.
- The new domestic fields being found are smaller and have shorter lives.

Source: API at: www.naturalgasfacts.org/factsheets/overview.html.

Natural Gas – Geothermal Can Help!

Aggressive geothermal deployment: the potential impact of 10,000 MW of new geothermal capacity, resulting in equal annual additions from 2005 to 2020.

This level of geothermal deployment is projected to lead to consumer gas savings of $6 to $15 billion!

Source: *Easing the Natural Gas Crisis: Reducing Natural Gas Prices through Increased Deployment of Renewable Energy and Energy Efficiency*, on web at: http:/eetd.lbl.gov/ea/ems/repubs.html.

Low & Uncertain Inventories: Coal

- Degradation and depletion of Central Appalachian supplies. Impacts spread to other regions.
- Coal stocks are near an all-time low.
- Rail coal transport cars are now in short supply.
- Low inventories mean scramble for supply.

Source: EIA *Monthly Energy Review – July 2004*, and EIA *Annual Energy Outlook with Projections to 2025*

Oil Prices Surge to Record Highs

Report from Goldman Sachs warns of a "super-spike" to **$105** a barrel in the next few years. CNN/Money, March 31, 2005

Oil sets record at **$56.46** per barrel. USA Today, March 17, 2005

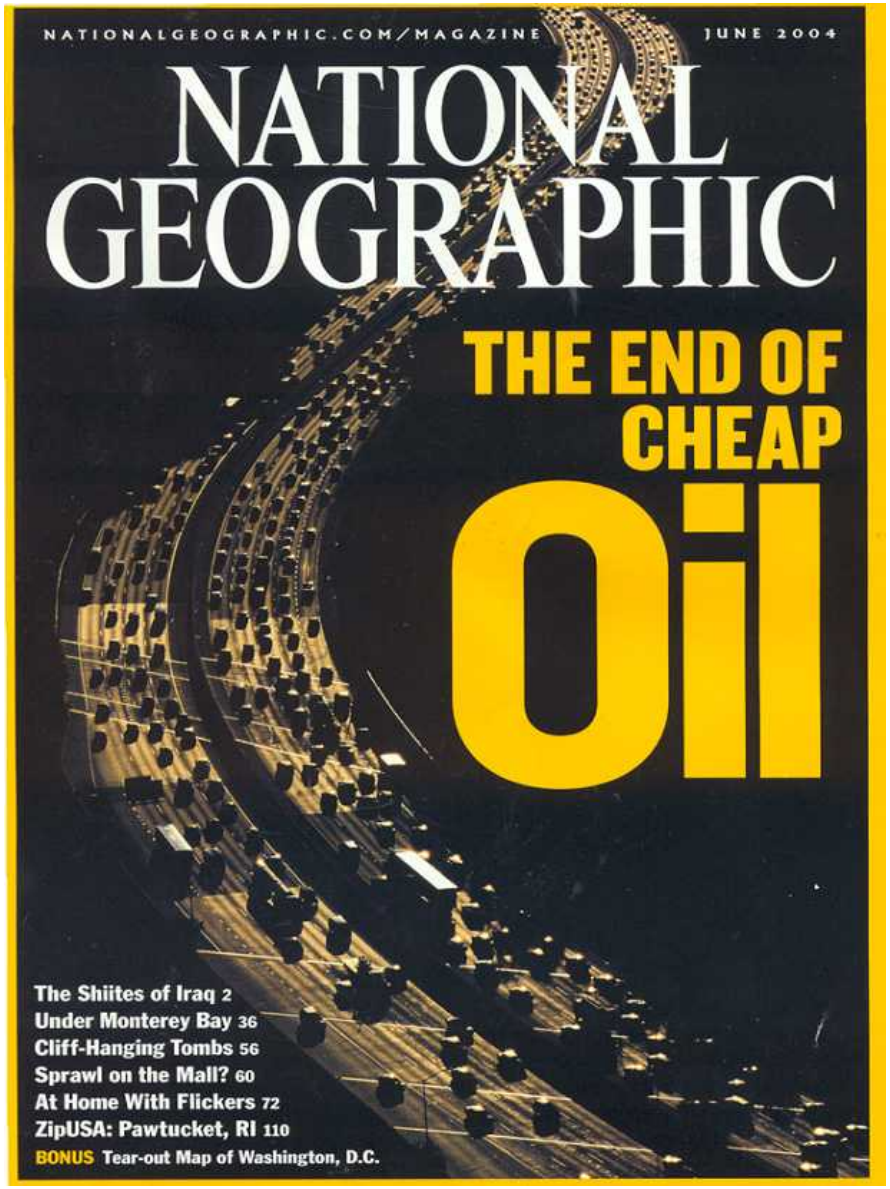
U.S. Crude Hits **$54.45** on Supply Woes. Reuters, Oct. 12, 2004

The U.S. trade deficit widened nearly 9 percent in October to a record $55.5 billion as **sky-high oil prices** helped propel imports into uncharted territory, the government said on Tuesday. Reuters, Dec. 14, 2004

Oil and National Security

Bin Laden called on militants to attack oil fields in Iraq and elsewhere in the region to drive up the price of oil. In the past, bin Laden has said the price of oil should be set at $100 a barrel. NBC News, Dec. 17, 2004

The Annual Energy Outlook Projects Oil Imports Will Increase 71% by 2025. U.S. Energy Information Administration, December 2004, www.eia.doe.gov/oiaf/aeo


NATIONALGEOGRAPHIC.COM/MAGAZINE
JUNE 2004
NATIONAL GEOGRAPHIC
THE END OF CHEAP
Oil
The Shiites of Iraq 2
Under Monterey Bay 36
Cliff-Hanging Tombs 56
Sprawl on the Mall? 60
At Home With Flickers 72
ZipUSA: Pawtucket, RI 110
BONUS Tear-out Map of Washington, D.C.

Global Climate Change

WASHINGTON (Reuters) -- Warmer temperatures in North America since 1950 were probably caused in part by human activity, the Bush administration said in a report that appeared to contradict the White House position there was no clear scientific proof on the causes of global warming.

Source: CNN, August 27, 2004, Web at: edition.cnn.com/2004/TECH/science/08/27/bc.environment.climate.reut

"There's little doubt that greenhouse gases released by industry, agriculture, automobiles, and coal-fired electric generation are a key factor in changing Earth's climate."

States File Lawsuits

"Landmark Suit Seeks Dramatic Carbon Dioxide Emission Reductions from Power Plants."

New York City and eight states—California, Connecticut, Iowa, New Jersey, New York, Rhode Island, Vermont, and Wisconsin—filed a landmark lawsuit against the country's five largest electric utilities on 21 July 2004. The utilities (American Electric Power Company, Southern Company, the Tennessee Valley Authority, Xcel Energy Inc., and Cinergy Corporation) produce about 25% of the U.S. electric power sector's carbon dioxide emissions.

Source: Press release from the Office of the New York Attorney General, July 21, 2004.
Web at: www.oag.state.ny.us/press/2004/jul/jul21a_04.html

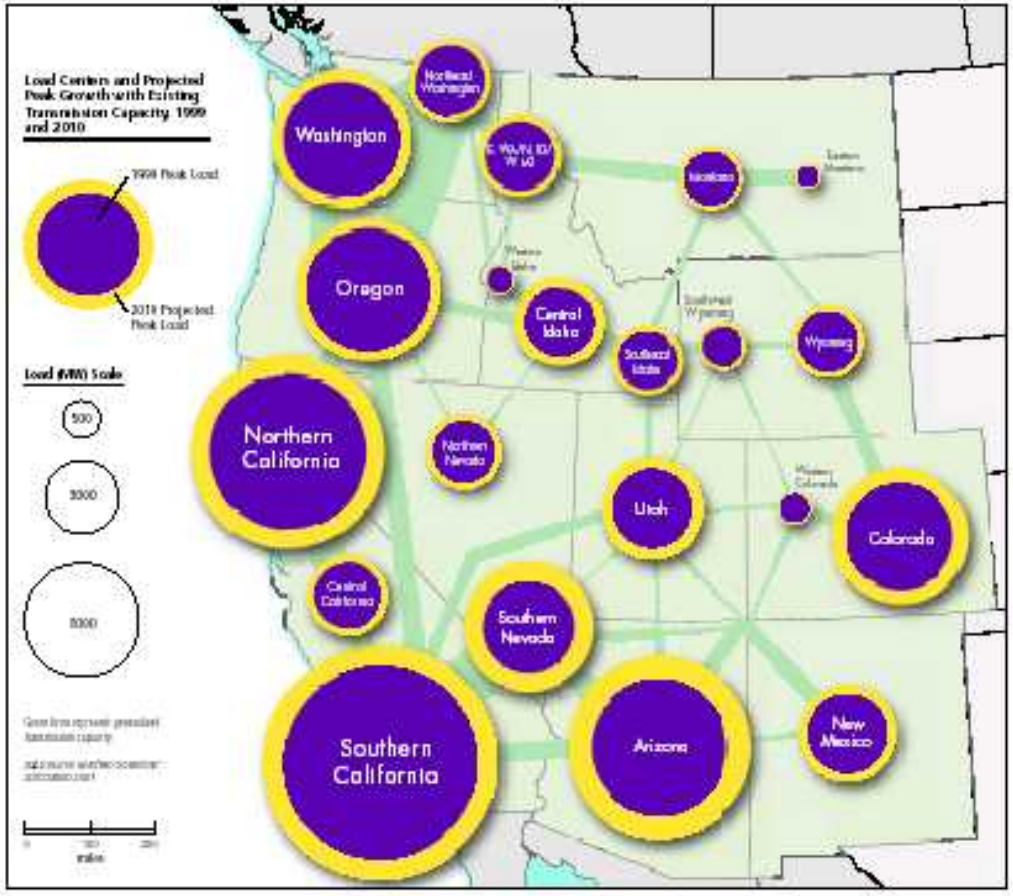
Rising Electricity Prices

5.2% Rise in National Electricity Prices Is One of Highest Recorded*.

"This year's increase... is one of the highest recorded for the United States and there is little sign that future electricity prices will abate" said Richard Soultanian, co-president of NUS Consulting.

* An annual survey conducted by NUS Consulting during the period of April 2004 to April 2005, website at: www.nusconsulting.com.

Load Growth in the Western U.S.



Resource Data International recently reported that the western U.S. would require about **90,000 megawatts** of new capacity by 2012. (Source: *Outlook for Power in North America*)

Utility Advantages

- 24–hour, steady, base-load power
- Dispatchable, base-load electricity
- Very reliable, >90% capacity factor
- 90 to 95% availability factor
- Virtually inexhaustible fuel source with good management practices
- Cost competitive (4 – 7 cents/kWh)

Geothermal Energy Getting Cheaper

1980: 10-16 cents/kWh

2000:
4 – 7 cents/kWh

- **Improved technology**
- **Reduced drilling costs**
- **Experience reduces risk**

2007 Goal: about 5 cents/kWh

Electricity Generation Comparison

Hydroelectric = 264,328,831 megawatt-hours

Biomass* = 61,521,675 megawatt-hours

Geothermal = 14,491,310 megawatt-hours

Wind = 10,354,279 megawatt-hours

Solar = 554,831megawatt-hours

*** Includes agricultural byproducts, crops,and landfill gas.**

Source: *Renewable Energy Trends 2003*, EIA, July 2004.

Electricity Generation Comparison

- **Geothermal**
  - Availability factor = >90%
  - Capacity factor = >90%
- **Wind**
  - Availability factor = >90%
  - Capacity factor = 25 to 30%

Sources: Public Renewables Partnership, (www.repartners.org/geothermal.htm), American Wind Energy Assoc., (www.awea.org/faq/basicen.html)

Comparative Plant Performance

Plant Type	Availability Factor	Capacity Factor
Geothermal	>90%	>90%
Wind	>90%	25 to 30%
Hydroelectric	~90%	30%
Natural Gas	95%	30%*
Coal	85 to 90%	70%
Nuclear	>90%	90%

* Peaking and load following operation.

Source: Public Renewables Partnership, (www.repartners.org/geothermal.htm), American Wind Energy Assoc., (www.awea.org/faq/basicen.html), EIA *Electric Power Annual 2002, Platt's Global Power Project Database* (projects in the U.S., Canada, Mexico and the UK scheduled for commissioning between the years 2000 and 2004).

Electricity Generation Comparison

Capital Costs*

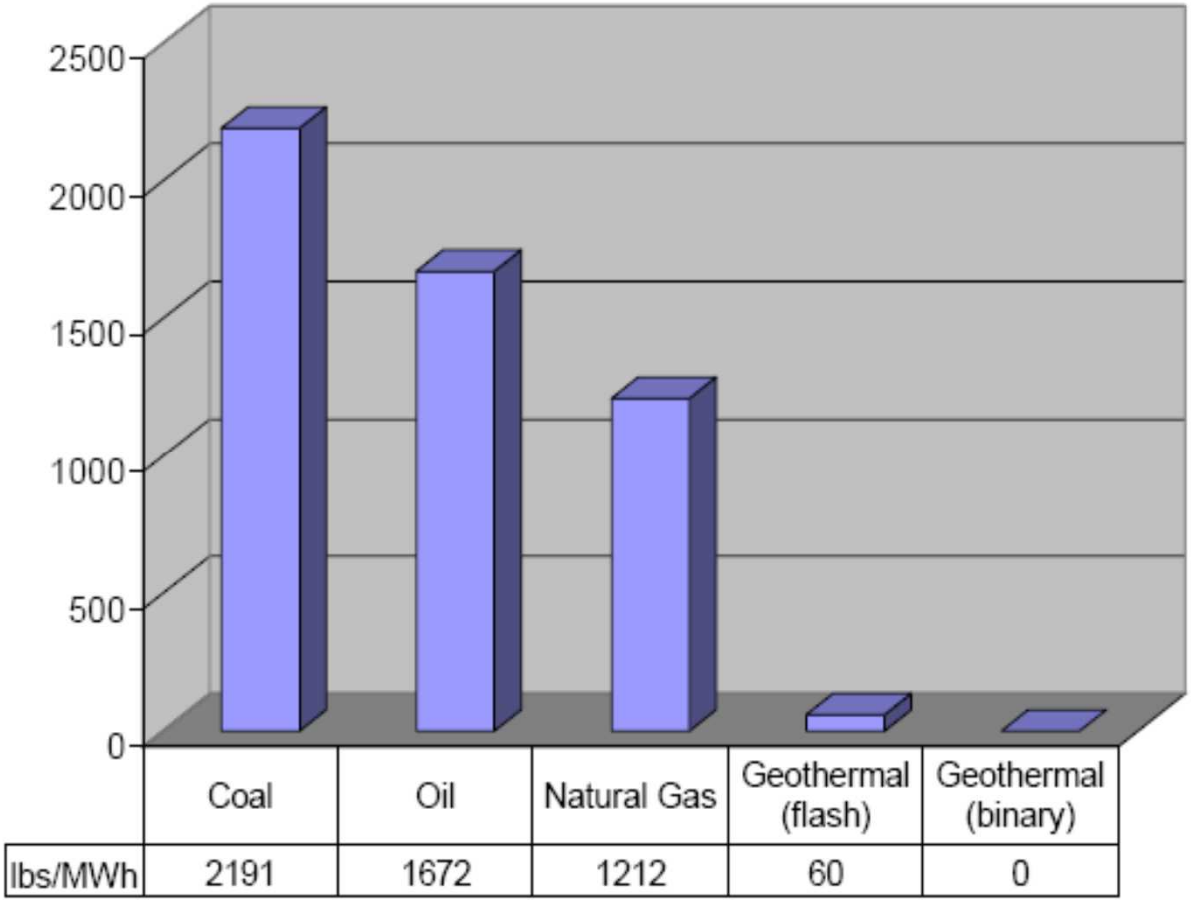
Geothermal	**$2500 to 3000**
Wind	**$2500**
Hydroelectric	**$2500**
Natural Gas	**$1100 to 1400**
Coal	**$2800 to 3000**
Nuclear	**$2500**

* Fully loaded; costs of land, site development, permitting, and zoning for the plant, the cost of the infrastructure to provide fuel to the plant, remove effluents, transmit the power to the grid (which may require adding grid capacity) and absorb carrying costs during construction. This may add from 25% to 50% to bare plant costs.

Source: *Platt's Global Power Project Database* (projects in the U.S., Canada, Mexico and the UK scheduled for commissioning between the years 2000 and 2004).

Geothermal Power Plants Blend in Well with the Environment

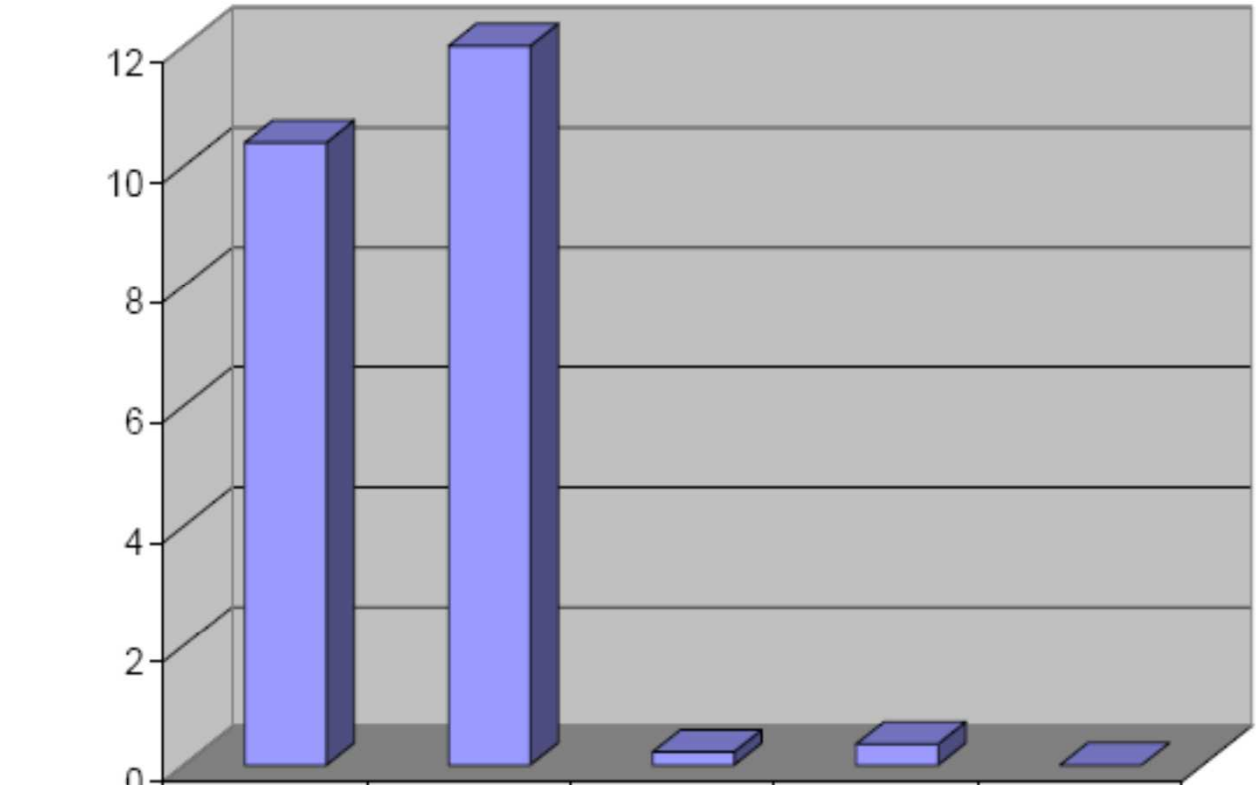
Carbon Dioxide Emissions Comparison



	Coal	Oil	Natural Gas	Geothermal (flash)	Geothermal (binary)
lbs/MWh	2191	1672	1212	60	0

Source: *A Guide to Geothermal Energy and the Environment*, Geothermal Energy Association, April, 2005, www.geo-energy.org/Facilities/Links/GeothermalGuide.pdf

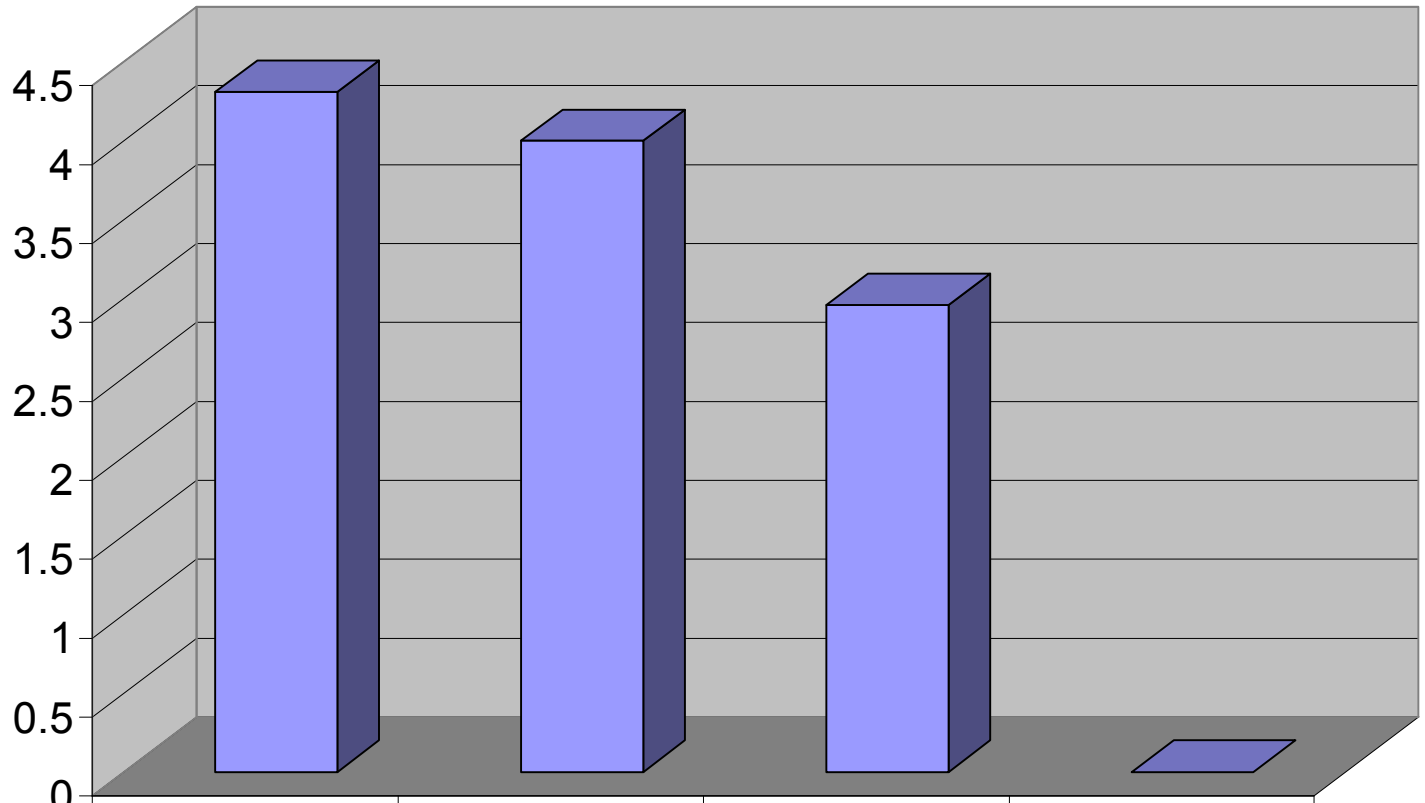
Sulfur Dioxide Emissions Comparison



	Coal	Oil	Natural Gas	Geothermal (Flash)	Geothermal (Binary)
Lbs/MWh	10.39	12	0.22	0.35	0

Source: *A Guide to Geothermal Energy and the Environment*, Geothermal Energy Association, April, 2005, www.geo-energy.org/Facilities/Links/GeothermalGuide.pdf

Nitrogen Oxide Comparison



	Coal	Oil	Natural Gas	Geothermal
Lbs/MWh	4.31	4	2.96	0

Source: *A Guide to Geothermal Energy and the Environment*, Geothermal Energy Association, April, 2005, www.geo-energy.org/Facilities/Links/GeothermalGuide.pdf

Coal versus Geothermal

- 10,837 times more sulfur dioxide,
- 3,865 times more nitrous oxide,
- and 23 times more carbon dioxide

per megawatt hour than a geothermal plant

Source: Coal data from Cherokee plant (Colorado) provided by Xcel Energy; Geothermal from the average of 11 Sonoma County steam power plants at The Geysers provided by Calpine Corporation as submitted to the Northern Sonoma County Air Pollution Control District for 2003 emissions inventory.

Coal and Geothermal Power Plant Comparison

Plant Name	Year	Total MWh produced during specified year	Primary Fuel	CO_2 Emissions Rate (lbs/MWh)	SO_2 Emissions Rate (lbs/MWh)	NOx Emissions Rate (lbs/MWh)
Cherokee (a coal-fired, steam-electric generating station)*	1997	4,362,809	Coal	2,077	7.23	6.64
Cherokee (a coal-fired, steam-electric generating station)	2003	5,041,966	Coal	2,154	2.33	4.02
Sonoma County power plant at The Geysers**	2003	5,076,925	Steam Geothermal	88.8	.000215	.00104
Mammoth Pacific***	2004	210,000+	Binary Geothermal	0	0	0

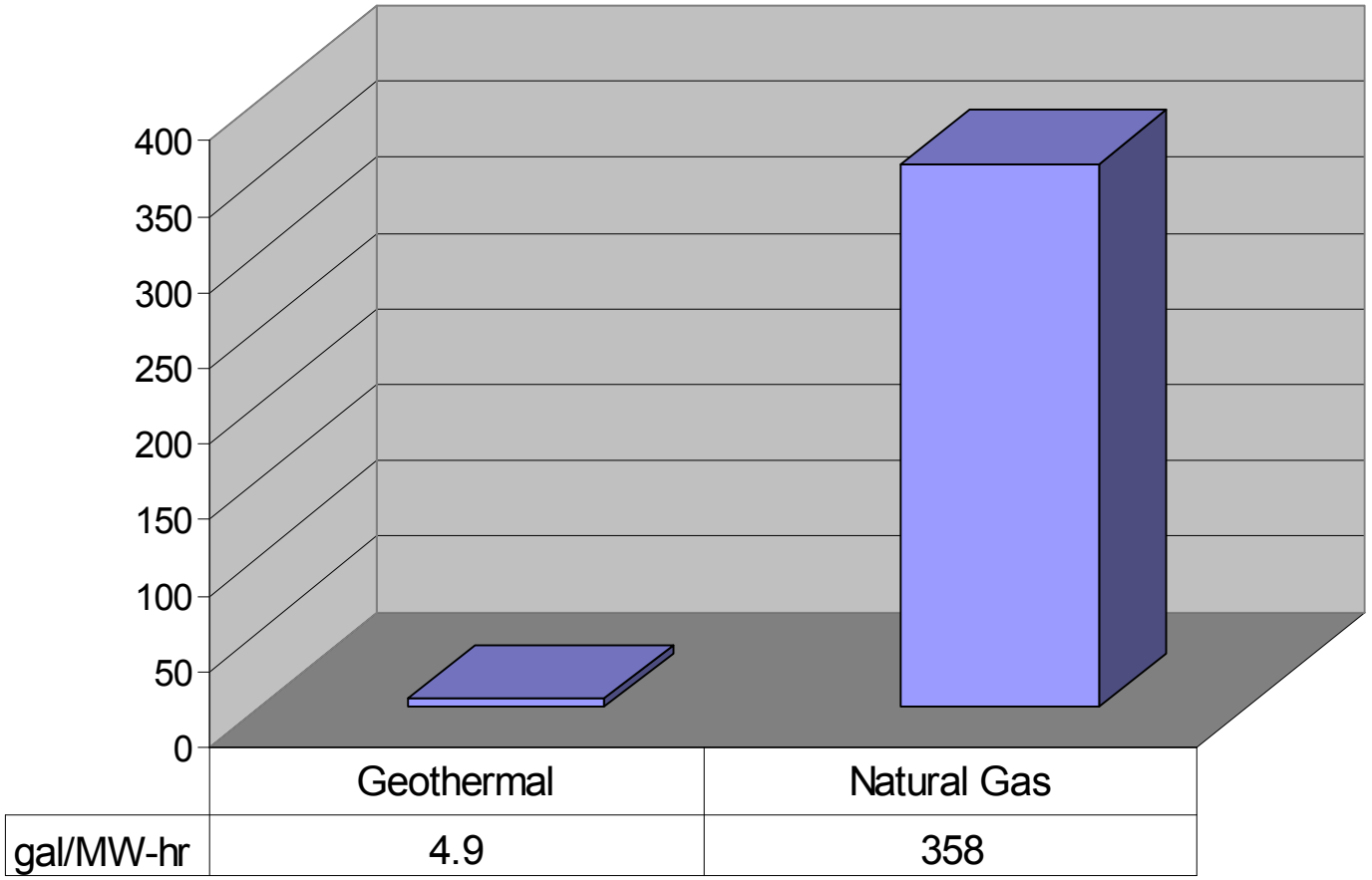
*Data on Cherokee plant (Colorado) provided by Xcel Energy.
**Values represent averages for 11 Sonoma County power plants at The Geysers. Data provided by Calpine Corporation as submitted to the Northern Sonoma County Air Pollution Control District for 2003 emissions inventory.
***Data provided by Bob Sullivan, plant manager at Mammoth Pacific, LP
+ Represents average yearly output rather than specific output for 2004.

"Mercury in many Lakes & Rivers"

- "States issued warnings for mercury and other pollutants in 2003 for nearly 850,000 miles of U.S. rivers — a **65% increase** over 2002."
- Mercury is emitted primarily by incinerators and **power plants that burn coal**.

Source: *USA Today*, August 24, 2004, EPA announcement.

Average Operational Freshwater Use



	Geothermal	Natural Gas
gal/MW-hr	4.9	358

Source: geothermal; Telephone Flat Environmental Impact Statement 3.2-32, 3.2-34, 3.2-35; natural gas; Calpine Corporation Sutter Power Plant Project, Application for Certification (AFC) (Dec 1997). Table 2.2-1, *Estimated Average Daily Water Requirements.*

Comparative Job Creation

The U.S. geothermal industry employs about 30,000 workers today.

Power Source	**Construction Employment** (jobs/MW)	**O&M Employment** (jobs/MW)	**Total Employment for 500 MW Capacity** (person-years)
Geothermal	4.0	1.7	27,050
Natural Gas	1.0	0.1	2,460

Source: *Renewable Energy and Jobs – Employment Impacts of Developing Markets for Renewables in California*, and based on California Renewable Technology Market and Benefits Assessment, Electric Power Research Institute, November 2001.

Geothermal Job Creation

California RPS-induced Geothermal Employment

Construction Employment for International Market	800 person/years
Construction Employment for In-State Market	1,230 person/years
Operating Employment for In-State Market	59,030 person/years
TOTAL	**61,060 person/years**

Source: *Renewable Energy and Jobs – Employment Impacts of Developing Markets for Renewables in California*, and based on *California Renewable Technology Market and Benefits Assessment*, Electric Power Research Institute, November 2001.

Cast Study – Fourmile Hill & Telephone Flat Geothermal Plant Economic Impacts

- Total impact on real income in the four-county region is **$113,925,512 gain**, and the yearly average gain is $3,797,517.
- Local government revenues for the four-county region **increase to a total of $3,030,276** for a 30-year period (assumed plant lifetime).

Source: *The Economic Impact of Calpine's Geothermal Development Projects in Siskiyou County, California*, Center for Economic Development California State University**,**June 2002, www.csuchico.edu/cedp/pdf/esp.calpine.pdf.

Geothermal Growth Potential

"Significant Increase" - Geothermal generation will increase from 13 billion kWh in 2003 to 33 billion kWh in 2025.

Source: Annual Energy Outlook 2025, DOE/EIA-0383(2005), Energy Information Administration, www.eia.doe.gov/oiaf/aeo/pdf/0383(2005).pdf.

Geothermal Growth Potential
California and western Nevada

Estimated resource capacity:

- Minimum capacity = 4700 MW
- Most-likely capacity = 6200 MW
- California alone; 3700 MW minimum and 4700 MW most-likely capacity.

Source: *New Geothermal Site Identification and Qualification*, April 2004, by GeothermEx, Inc., for the California Energy Commission, CEC publication # P500-04-051, www.geothermex.com/CEC_PIER.htm.

New Power Plants and GPW

Since the creation of GPW, about 550 MW of new geothermal development for power production has been identified.

- **California –** Bottle Rock Power Plant (55 MW), Salton Sea #6 (185 MW), Four Mile Hill (50 MW), Telephone Flat (50 MW)

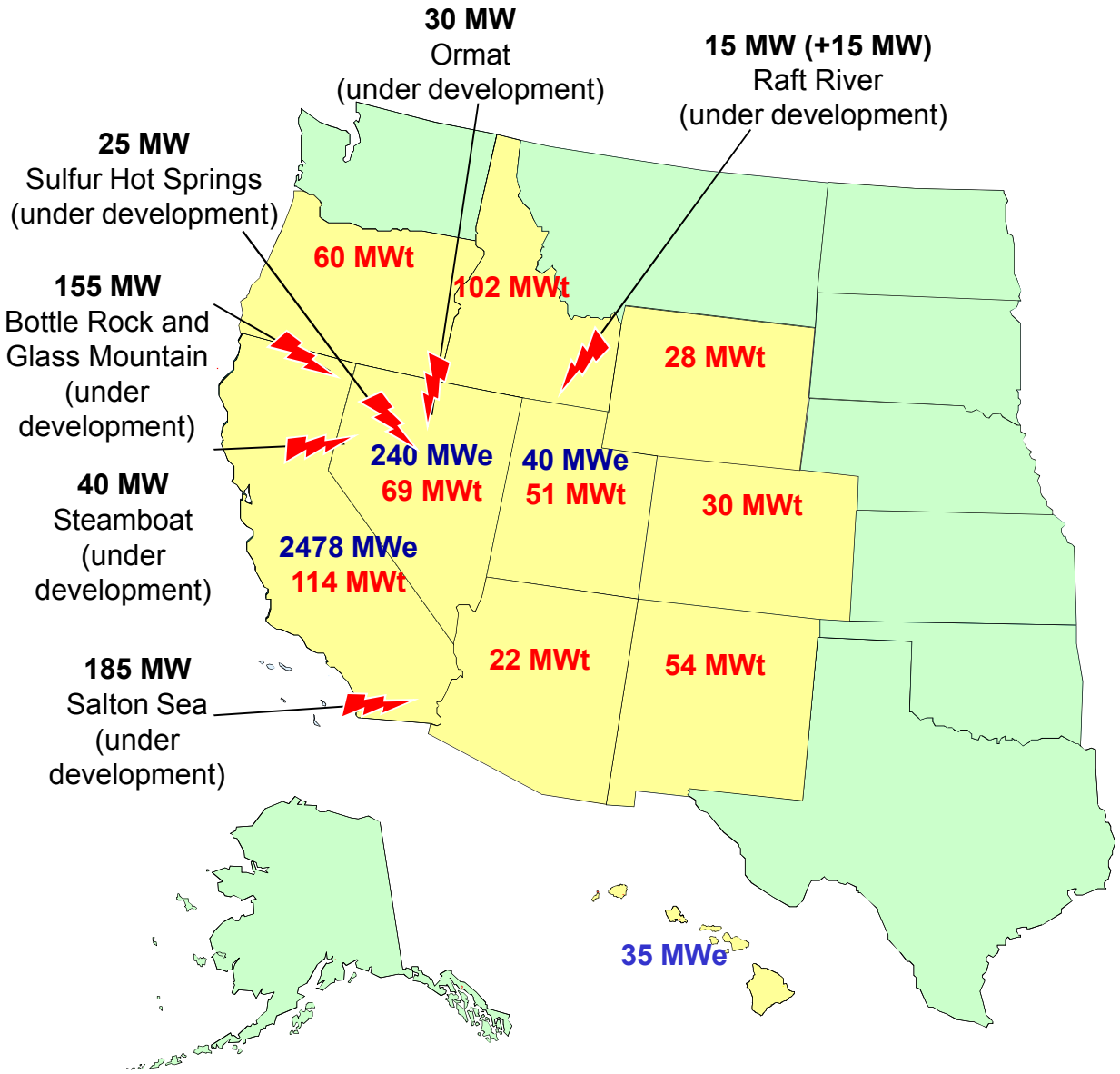
  Subtotal = **340 MW**
- **Idaho –** Raft River Project, 15 MW (Phase 1), 15 MW (Phase 2), Willow Springs (100 MW)

  Subtotal = **115 MW**
- **Nevada –** Elko, Washoe (Steamboat IV), and Churchill Counties, 95 MW

  Subtotal = **95 MW**

TOTAL = 550 MW

Source: Geothermal Energy Association Website, www.geo-energy.org/Developing.htm.



Installed and Planned:

About 2750 MW (electric)

Over 600 MW (thermal)

550 MW under development (elec.)

- **Geothermal Power in 24 Countries***
- **Meets the Needs of 60 Million People**
  - **25% in the Philippines, Iceland, and El Salvador.**
  - **30% in Tibet.**

*** Australia, China, Costa Rica, El Salvador, Ethiopia, France, Guatemala, Iceland, Indonesia, Italy, Japan, Kenya, Mexico, New Zealand, Nicaragua, Philippines, Portugal, Russia, Taiwan, Thailand, Tibet, Turkey, United States, and Zambia**

This small binary power plant is in Fang, Thailand.

Geothermal energy is already making a significant contribution to U.S. energy needs.

Geothermal energy technologies are poised to make an even greater contribution.