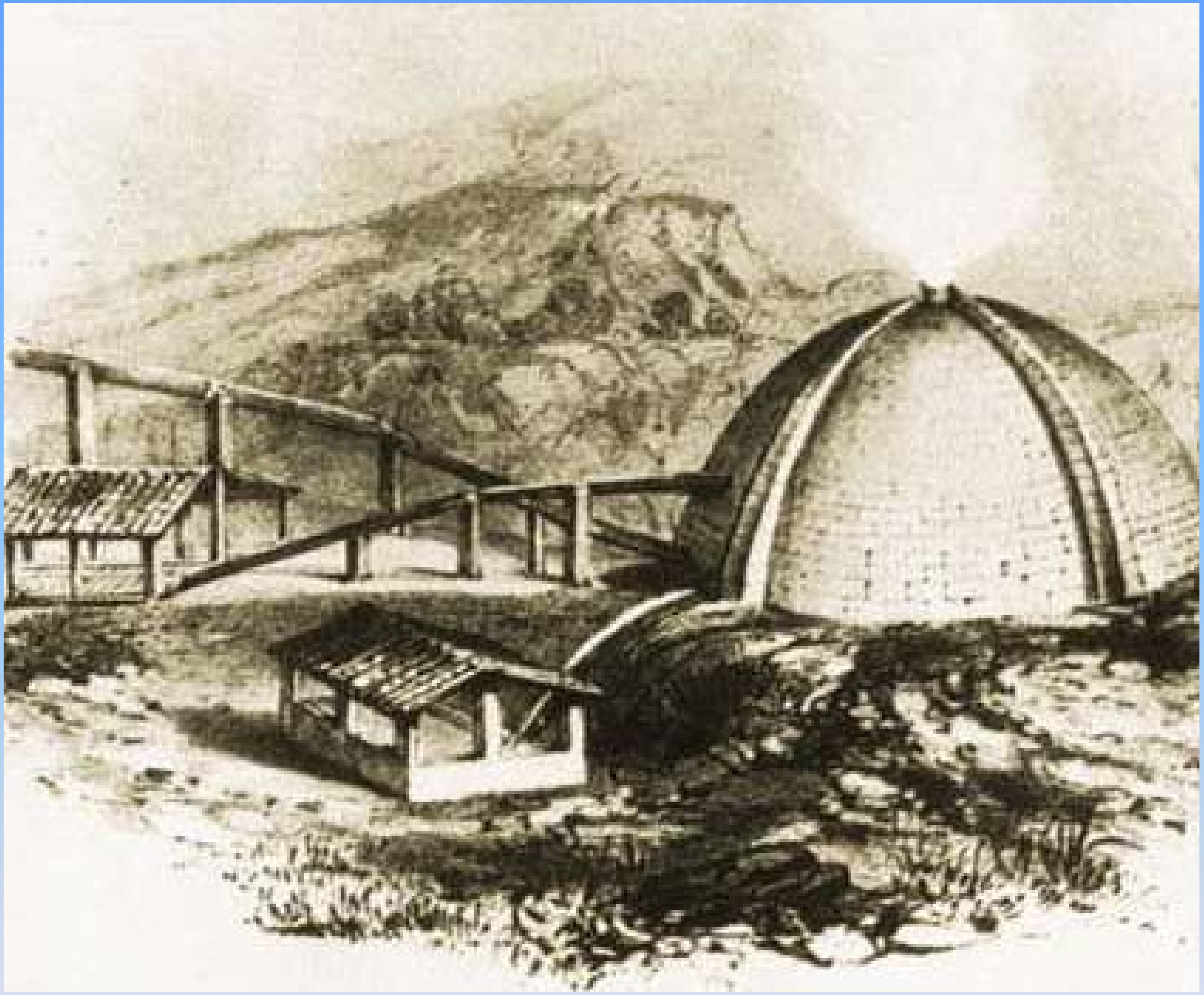
GEOTHERMAL 101

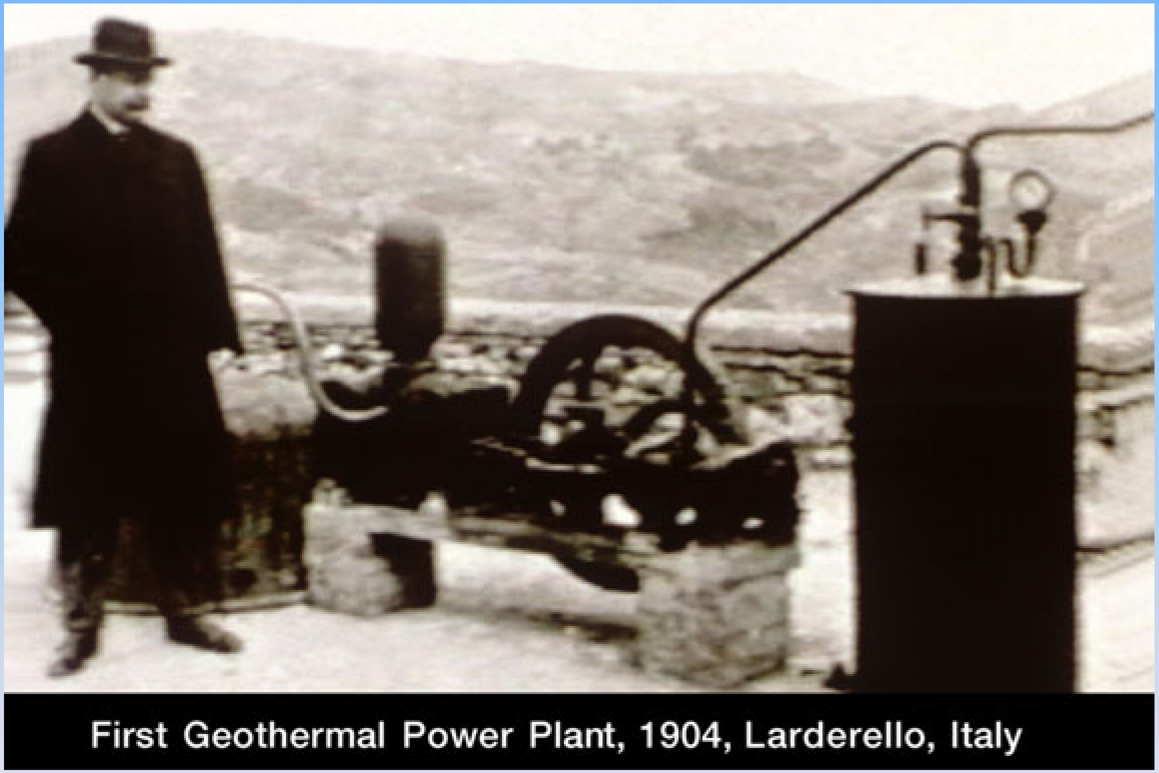
Geology & Geothermal Resources

Geothermal Leasing & Implementation Workshops
April, May and June 2009



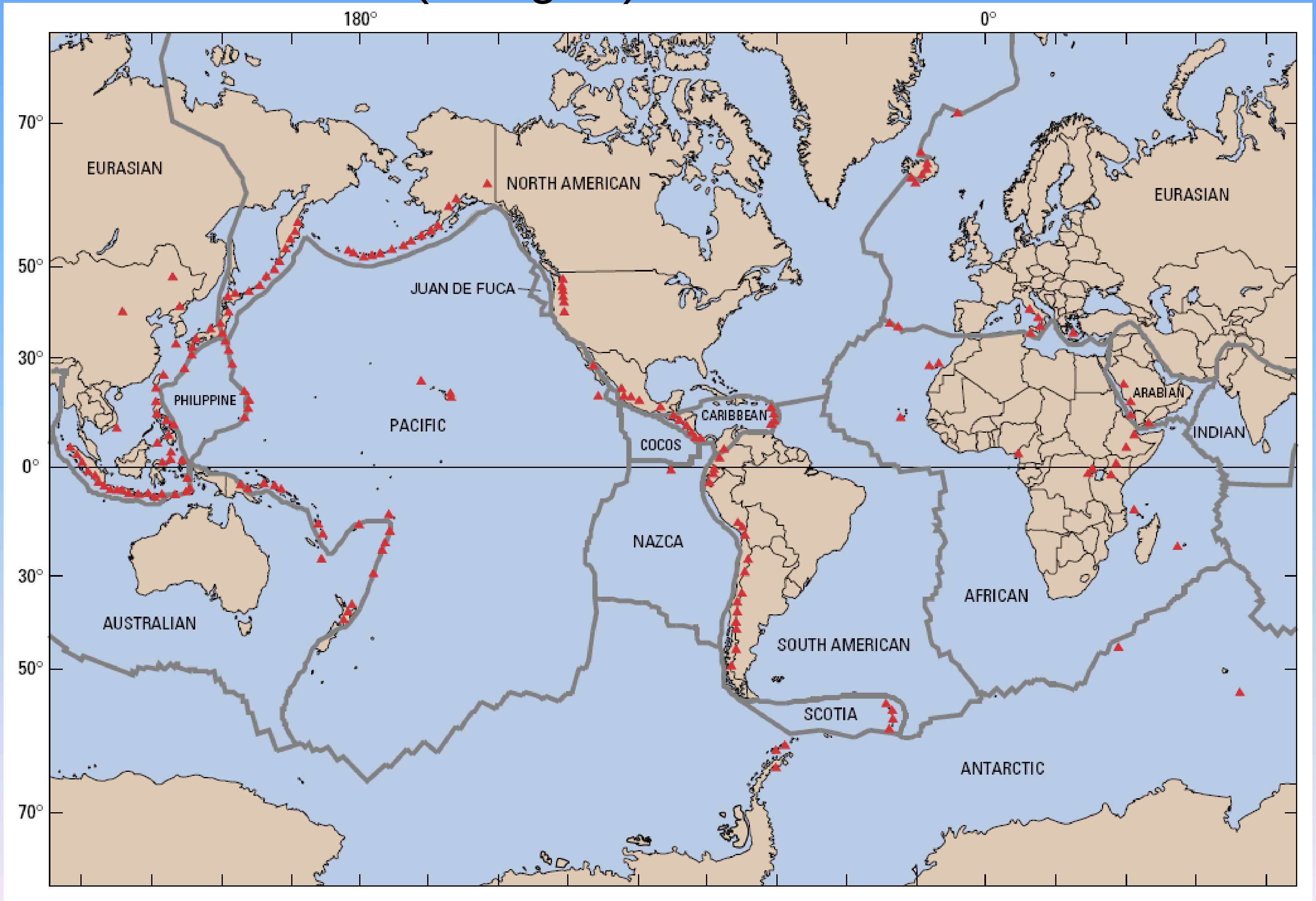
The “covered lagoon” used in the first half of the 19th century in the Larderello area, Italy, to collect the hot boric waters and extract the boric acid.

World's 1st Geothermal Power Plant



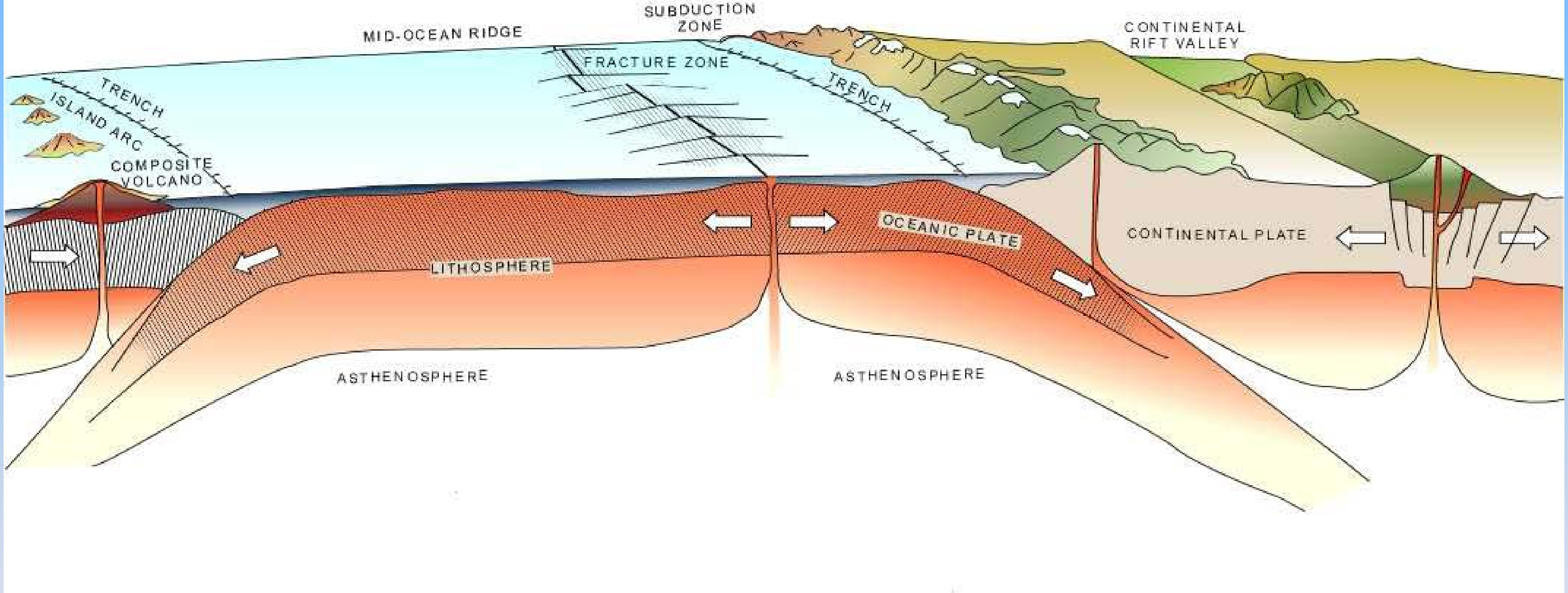
The engine used at Larderello in 1904 in the first experiment in generating electric energy from geothermal steam, along with its inventor, Prince Piero Ginori Conti.

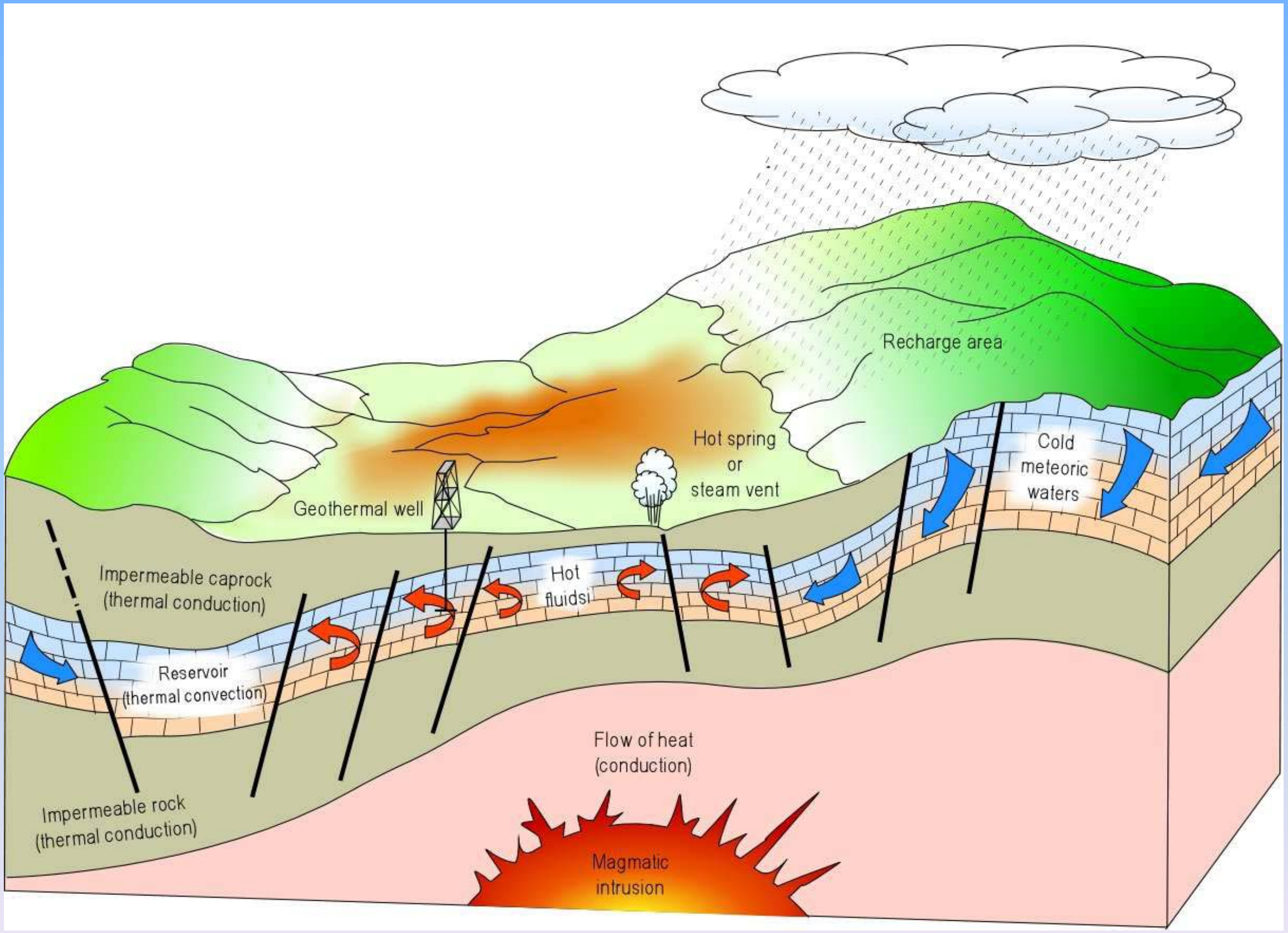
Earth' s main lithospheric plates and some of the world's active volcanoes (triangles)

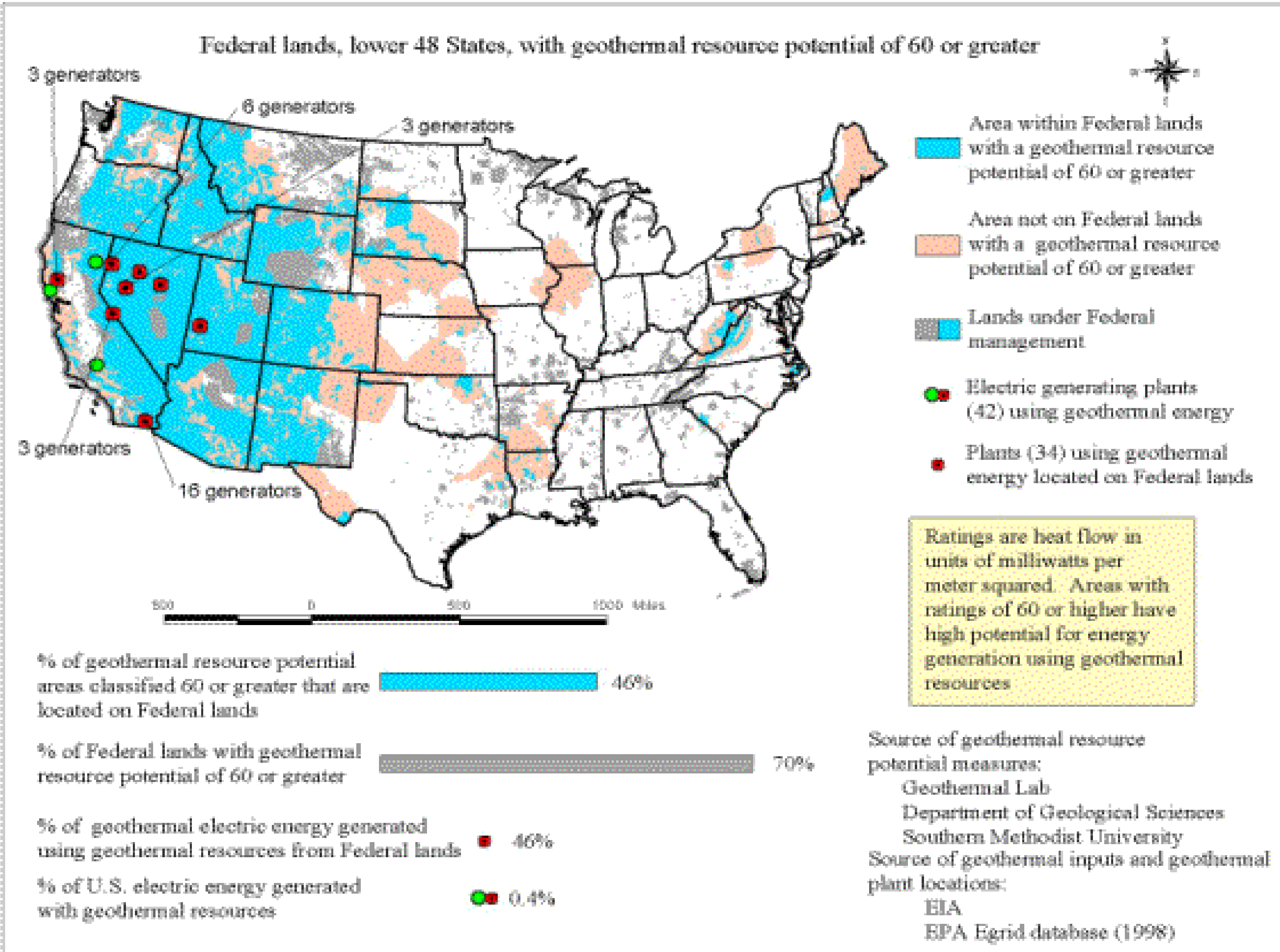


From USGS Circular 1249.

Schematic cross-section showing plate tectonic processes



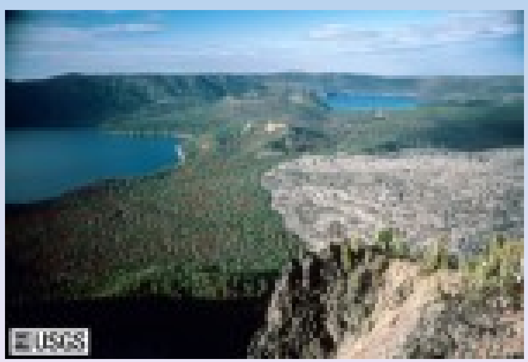

Recharge area
Hot spring
or
steam vent
Geothermal well
Cold
meteoric
waters
Impermeable caprock
(thermal conduction)
Hot
fluidsi
Reservoir
(thermal convection)
Flow of heat
(conduction)
Impermeable rock
(thermal conduction)
Magmatic
intrusion

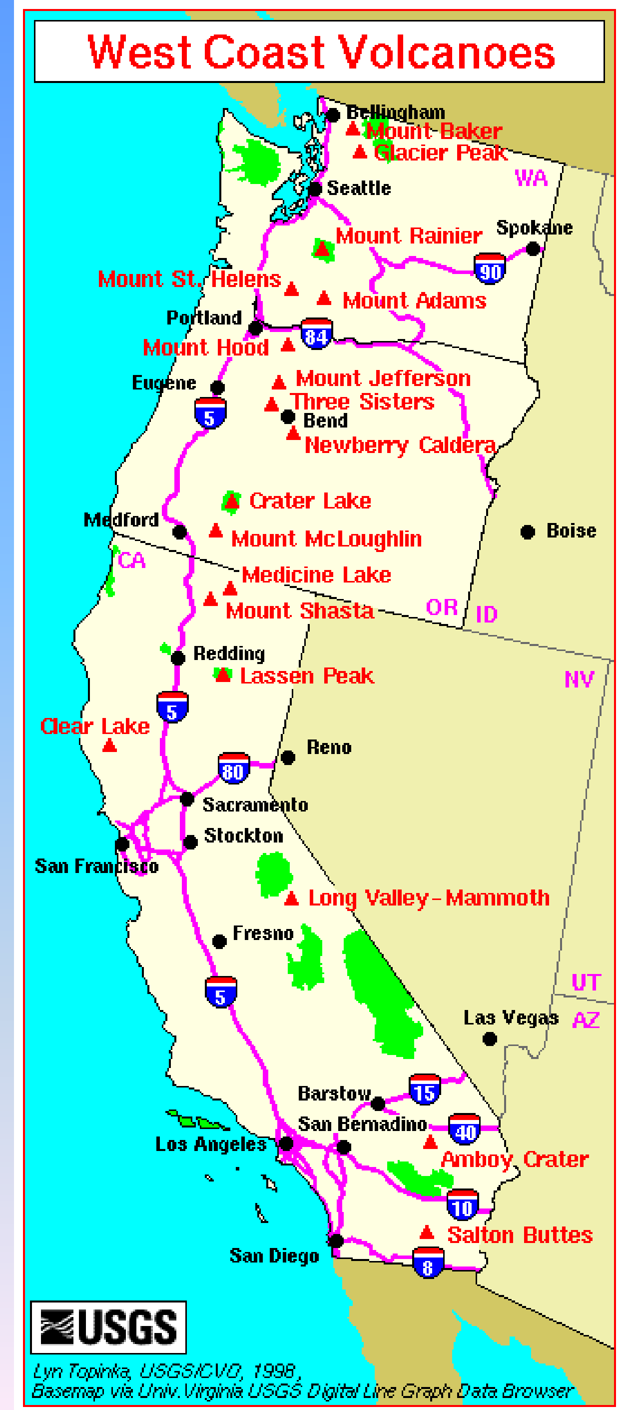

Federal lands, lower 48 States, with geothermal resource potential of 60 or greater
3 generators
6 generators
3 generators
3 generators
16 generators
500
0
500
1000 Miles
Area within Federal lands with a geothermal resource potential of 60 or greater
Area not on Federal lands with a geothermal resource potential of 60 or greater
Lands under Federal management
Electric generating plants (42) using geothermal energy
Plants (34) using geothermal energy located on Federal lands
Ratings are heat flow in units of milliwatts per meter squared. Areas with ratings of 60 or higher have high potential for energy generation using geothermal resources
% of geothermal resource potential areas classified 60 or greater that are located on Federal lands
46%
% of Federal lands with geothermal resource potential of 60 or greater
70%
% of geothermal electric energy generated using geothermal resources from Federal lands
46%
% of U.S. electric energy generated with geothermal resources
0.4%
Source of geothermal resource potential measures:
Geothermal Lab
Department of Geological Sciences
Southern Methodist University
Source of geothermal inputs and geothermal plant locations:
EIA
EPA Egrid database (1998)

Fumarole–Mount Hood

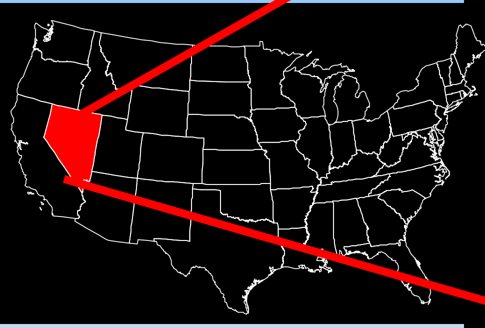
Mount Hood

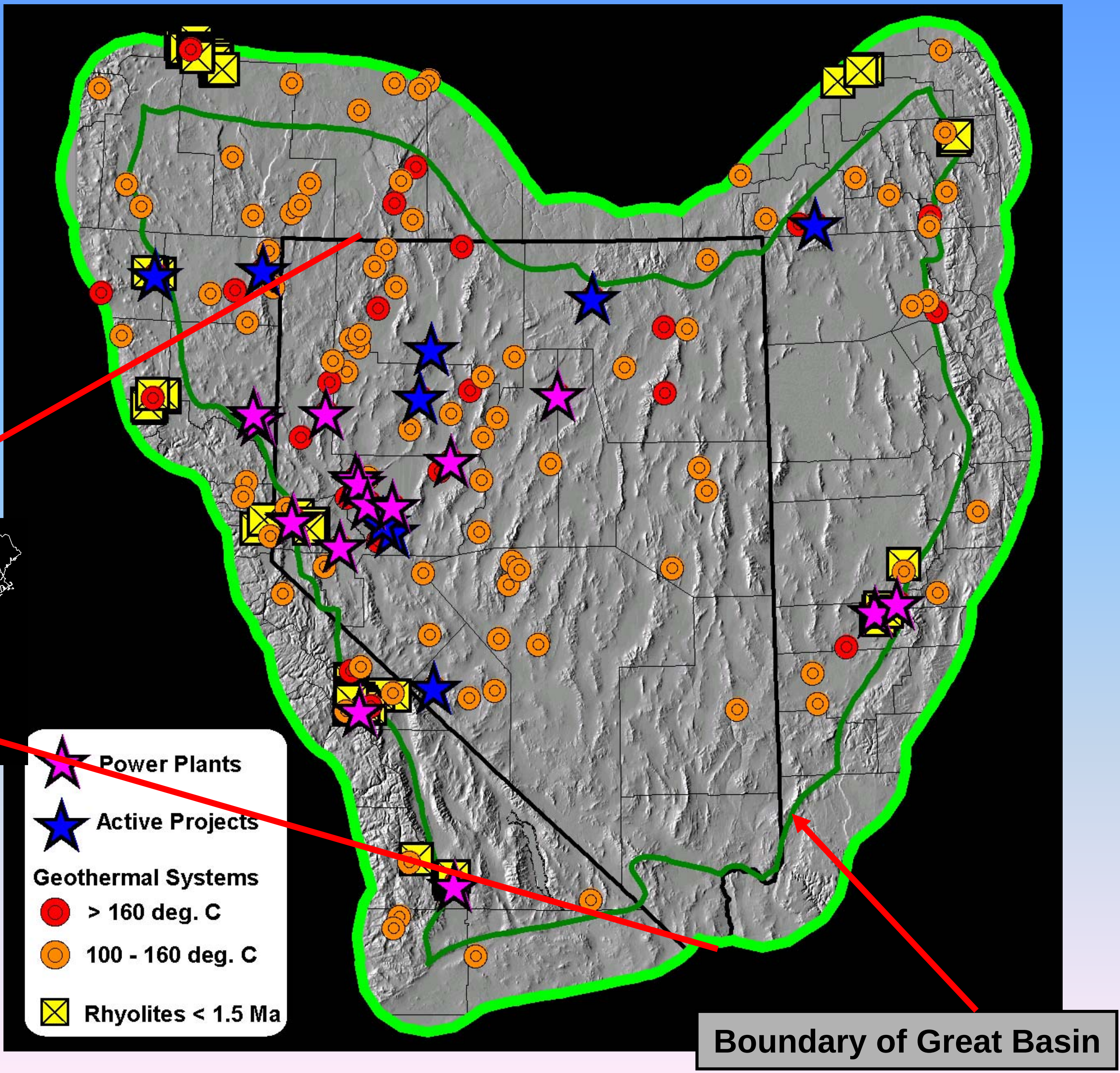
Newberry Crater





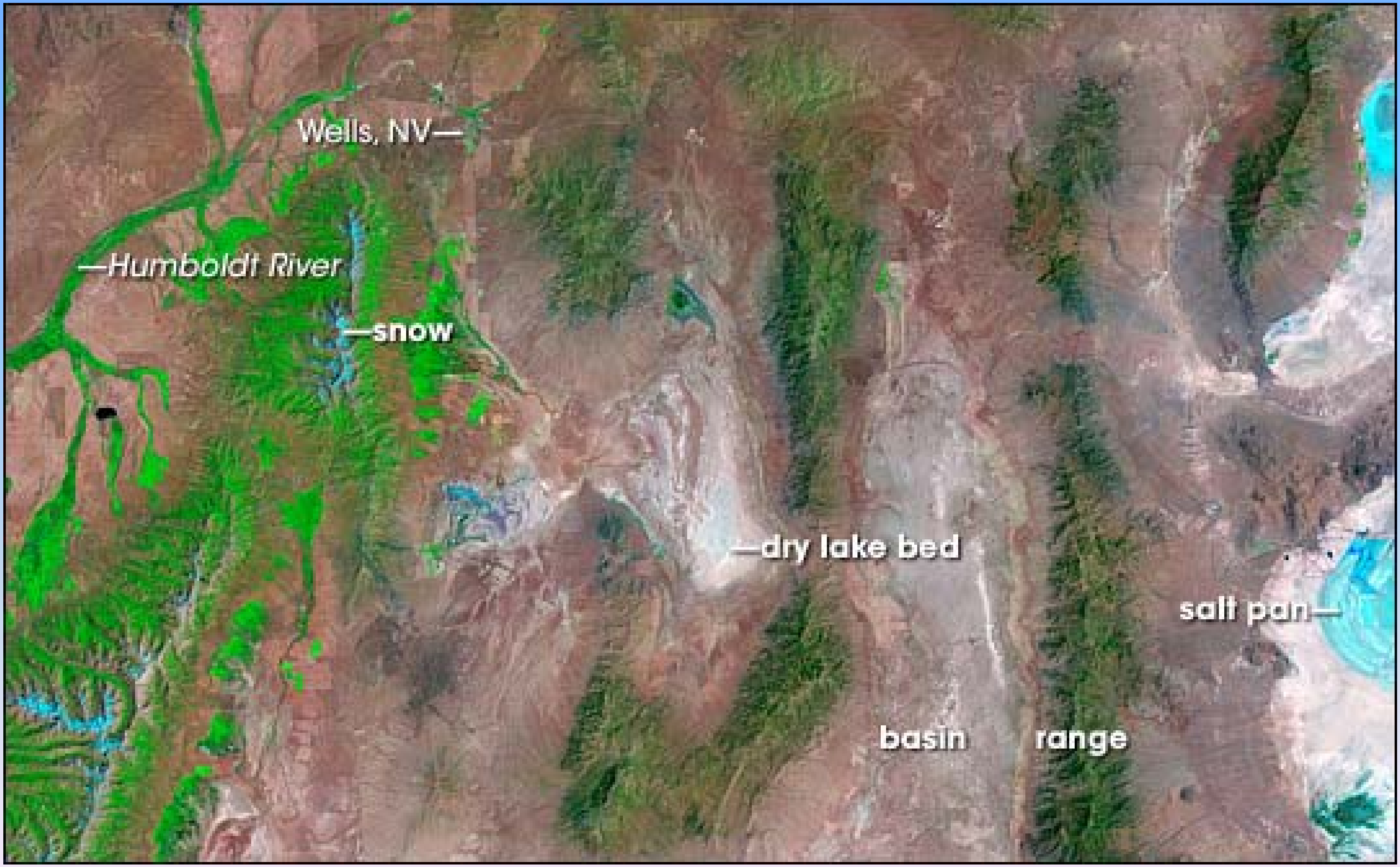
Geothermal Systems in Nevada & Great Basin, USA





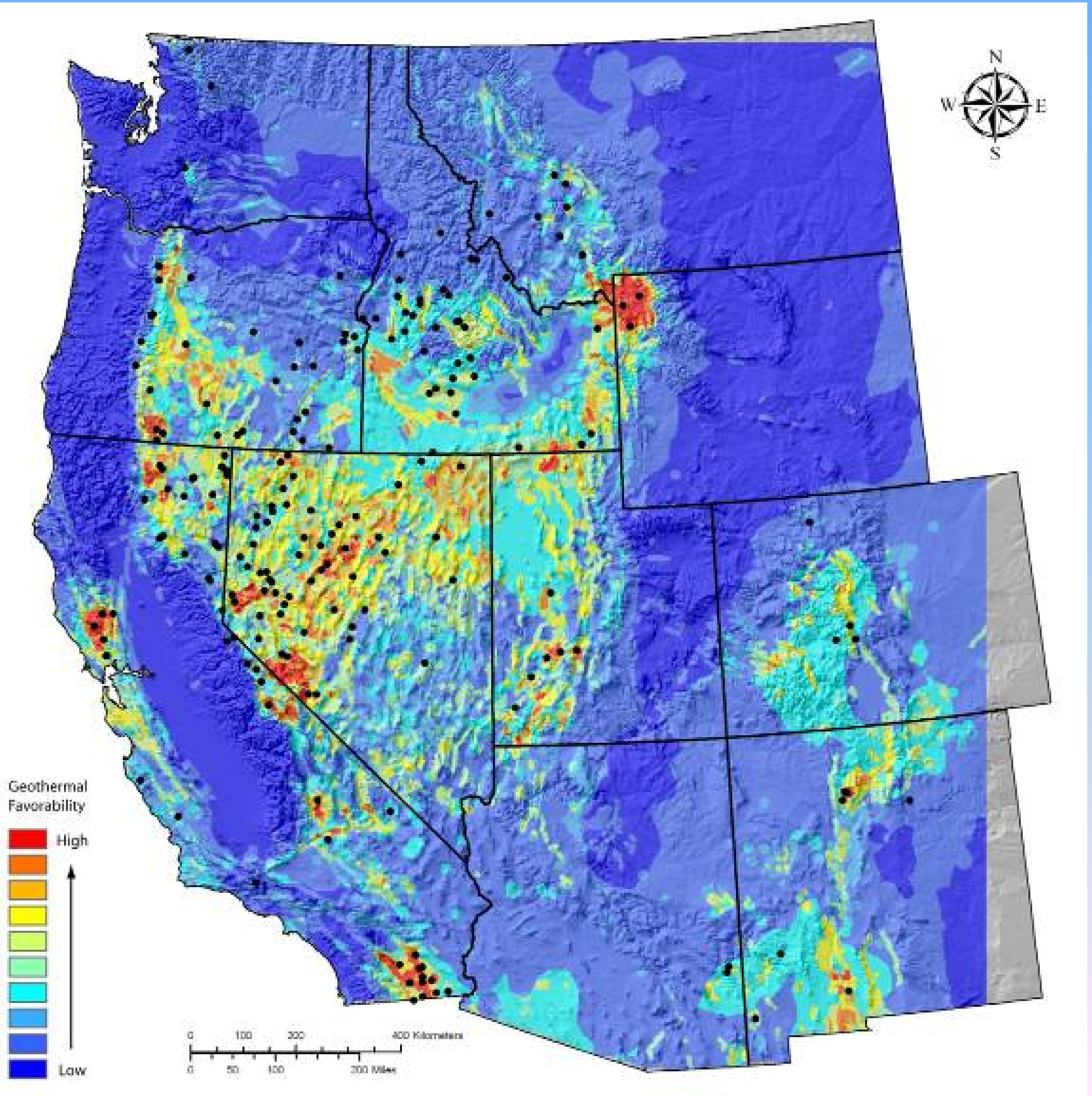
From: Great Basin Center, 2004

Typical Basin and Range Topography



Undiscovered Resources – Geothermal Favorability Maps

Warmer colors represent high probability for the presence of geothermal systems



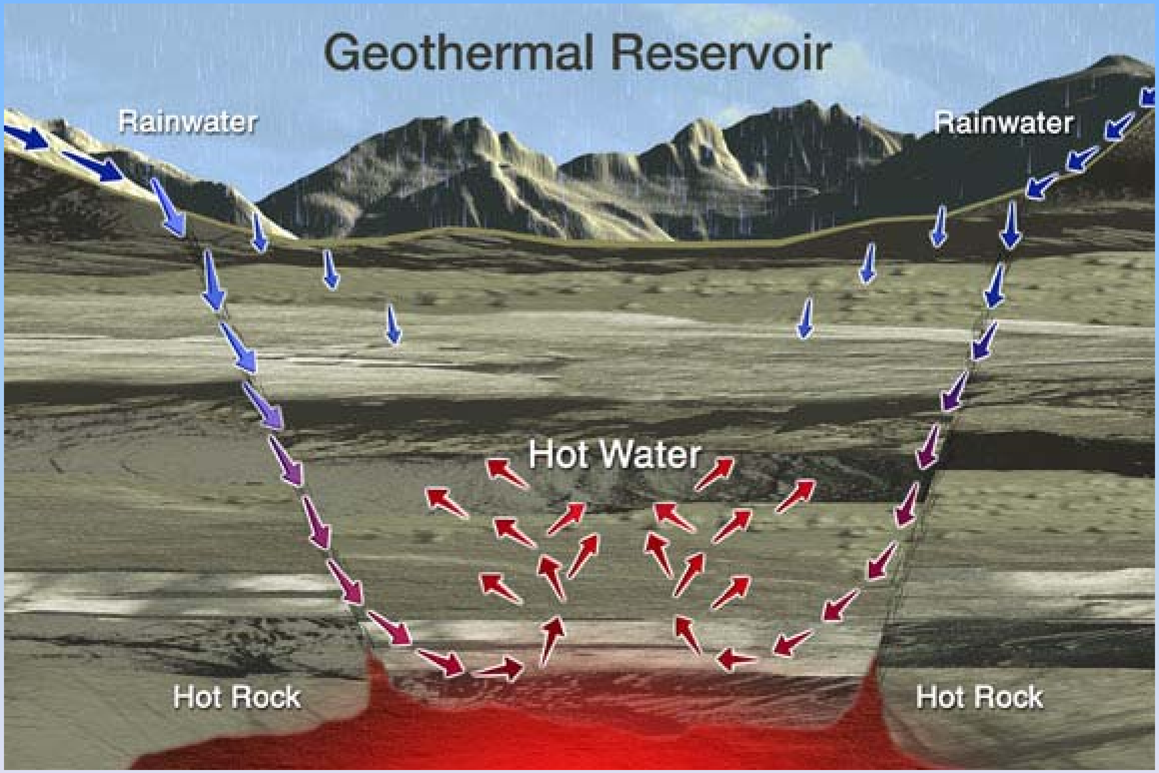
USGS

Geothermal Resources

(USGS Fact Sheet 2008-3062)

	Identified (Mwe)	Undiscovered (Mwe)	EGS (Mwe)
CA:	5,140	9,532	47,100
NV:	1,216	3,243	101,300
AK:	606	1,428	NA
OR:	485	1,406	61,500
HI:	169	2,027	NA
NM:	153	1,103	54,400
UT:	171	1,088	46,500
MT:	51	573	16,100
WY:	31	129	2,900
WA:	20	223	6,300
AZ:	20	775	52,900
CO:	11	821	51,300

Typical Geologic Environment (Hydrothermal Reservoir)



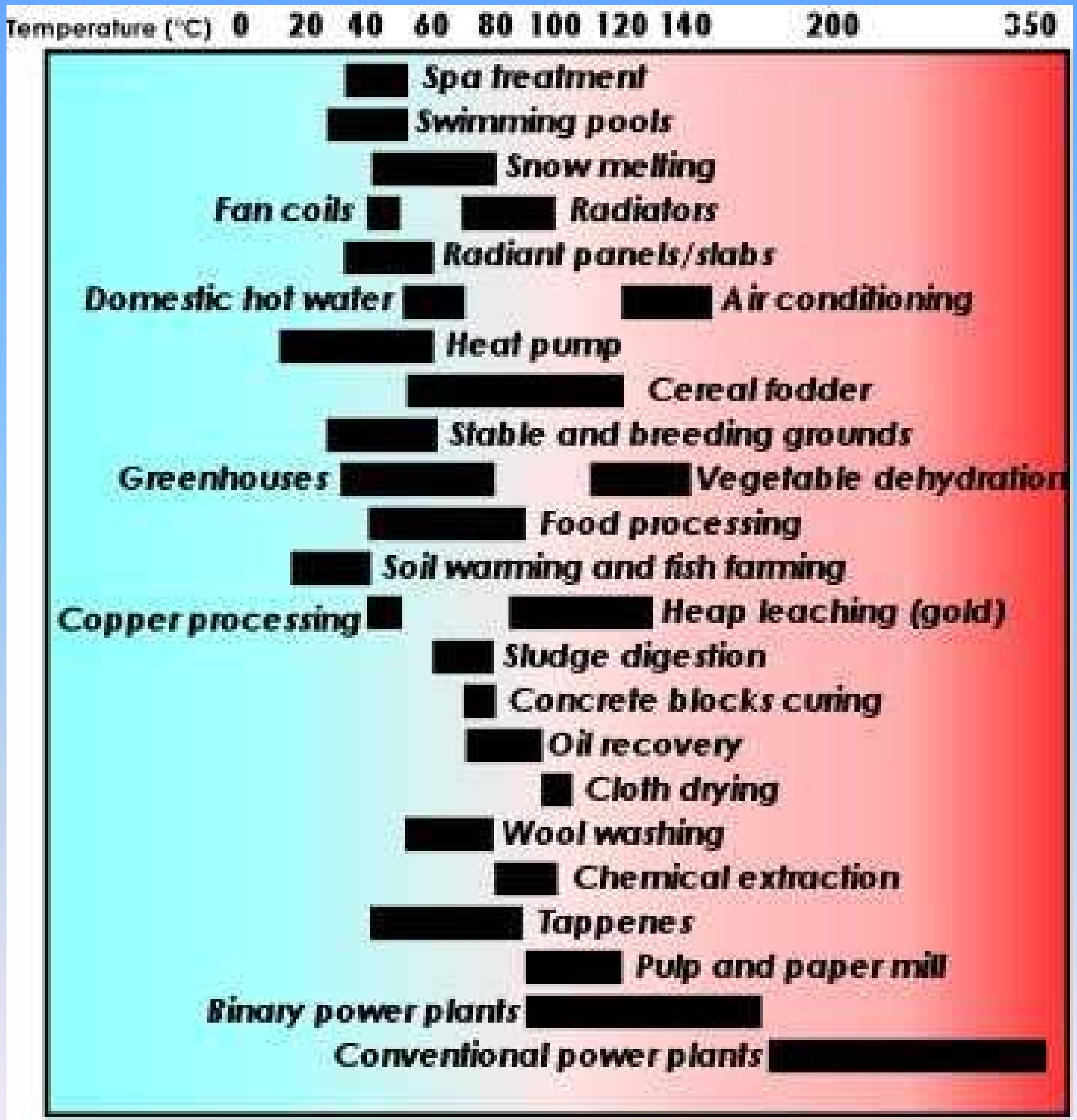
Hot Creek
Mammouth Lakes, CA

Geothermal Environments

- Hydrothermal Systems
  - High Temperature (>150°C)
    - Liquid- and Vapor -Dominated
  - Moderate Temperature (90 to 150°C)
    - Liquid-Dominated
  - Low Temperature (<90°C)
    - Liquid-Dominated
- Hot Dry Rock
  - Enhanced (Engineered) Geothermal System
- Cogeneration
  - Oil and Gas
  - Geopressure

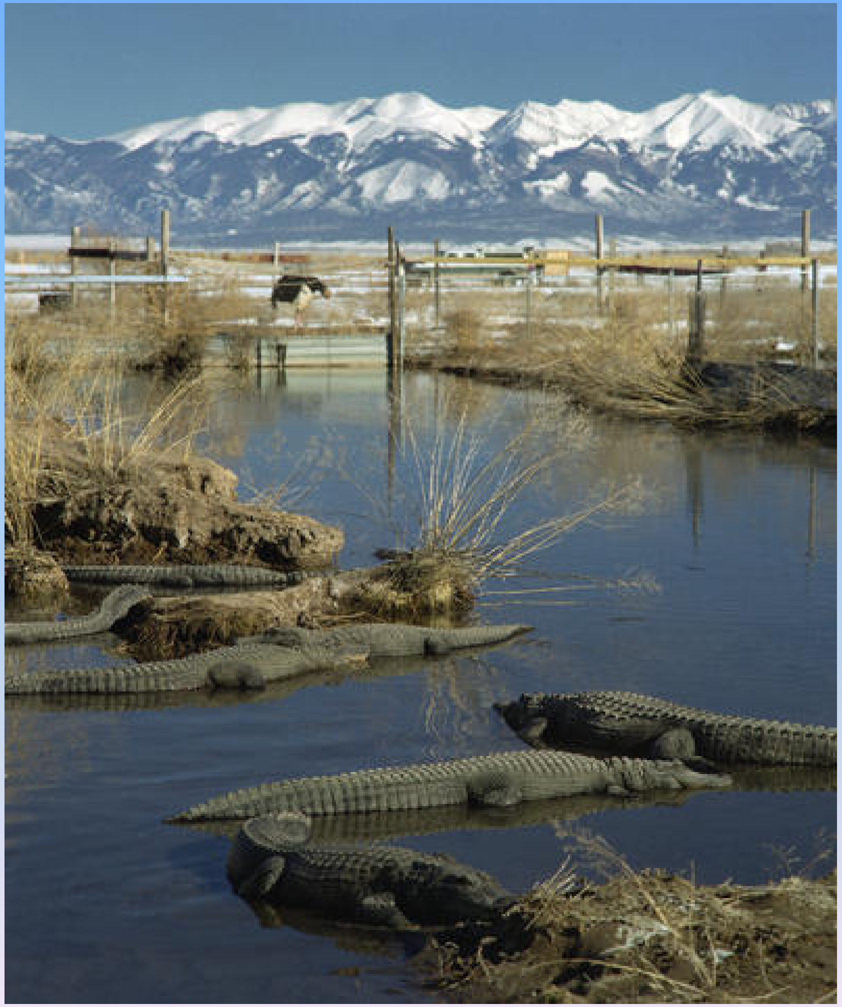
Geologic Environment

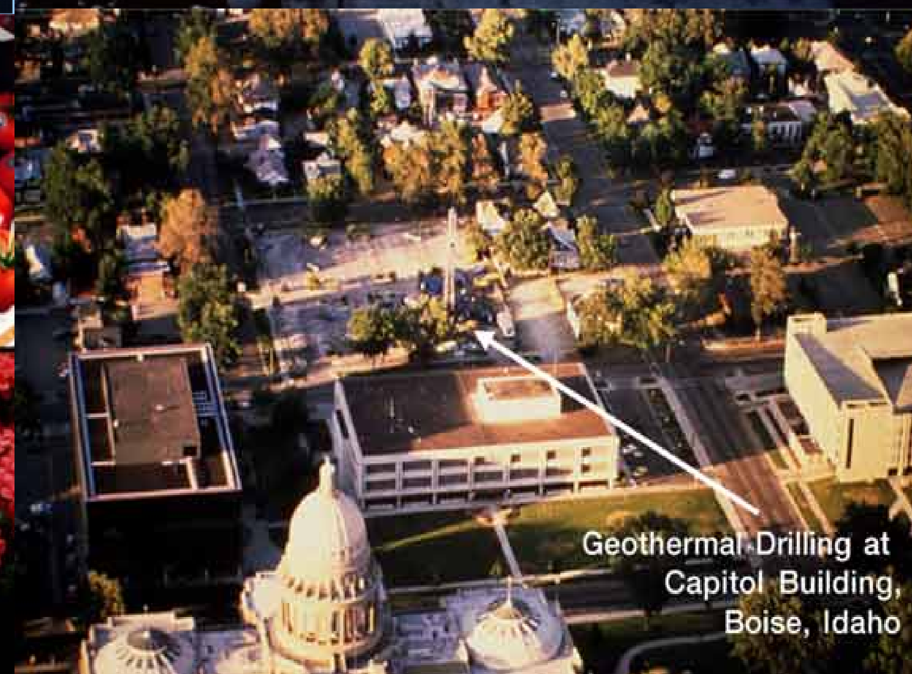
- Magmatic /Volcanic
  - Vapor-Dominated (The Geysers)
  - Liquid-Dominated (Salton Sea, Valles Caldera, Long Valley, Coso)
- Tectonic Systems (Crustal extension, rift valleys)
  - High Heat Flow Settings (Dixie Valley, other Great Basin)
- Volcanic
  - Andesitic (Cascades)
  - Basaltic (Hawaii)


Temperature (°C) 0 20 40 60 80 100 120 140 200 350
Spa treatment
Swimming pools
Snow melting
Fan coils
Radiators
Radiant panels/slabs
Domestic hot water
Air conditioning
Heat pump
Cereal fodder
Stable and breeding grounds
Greenhouses
Vegetable dehydration
Food processing
Soil warming and fish farming
Copper processing
Heap leaching (gold)
Sludge digestion
Concrete blocks curing
Oil recovery
Cloth drying
Wool washing
Chemical extraction
Tappenes
Pulp and paper mill
Binary power plants
Conventional power plants

Direct Use

- Space heat (either individual buildings or whole towns)
- Rising plants in greenhouses
- Drying crops
- Heating water at fish farms
- Industrial processes, such as pasteurizing milk
- Dehydrating vegetables

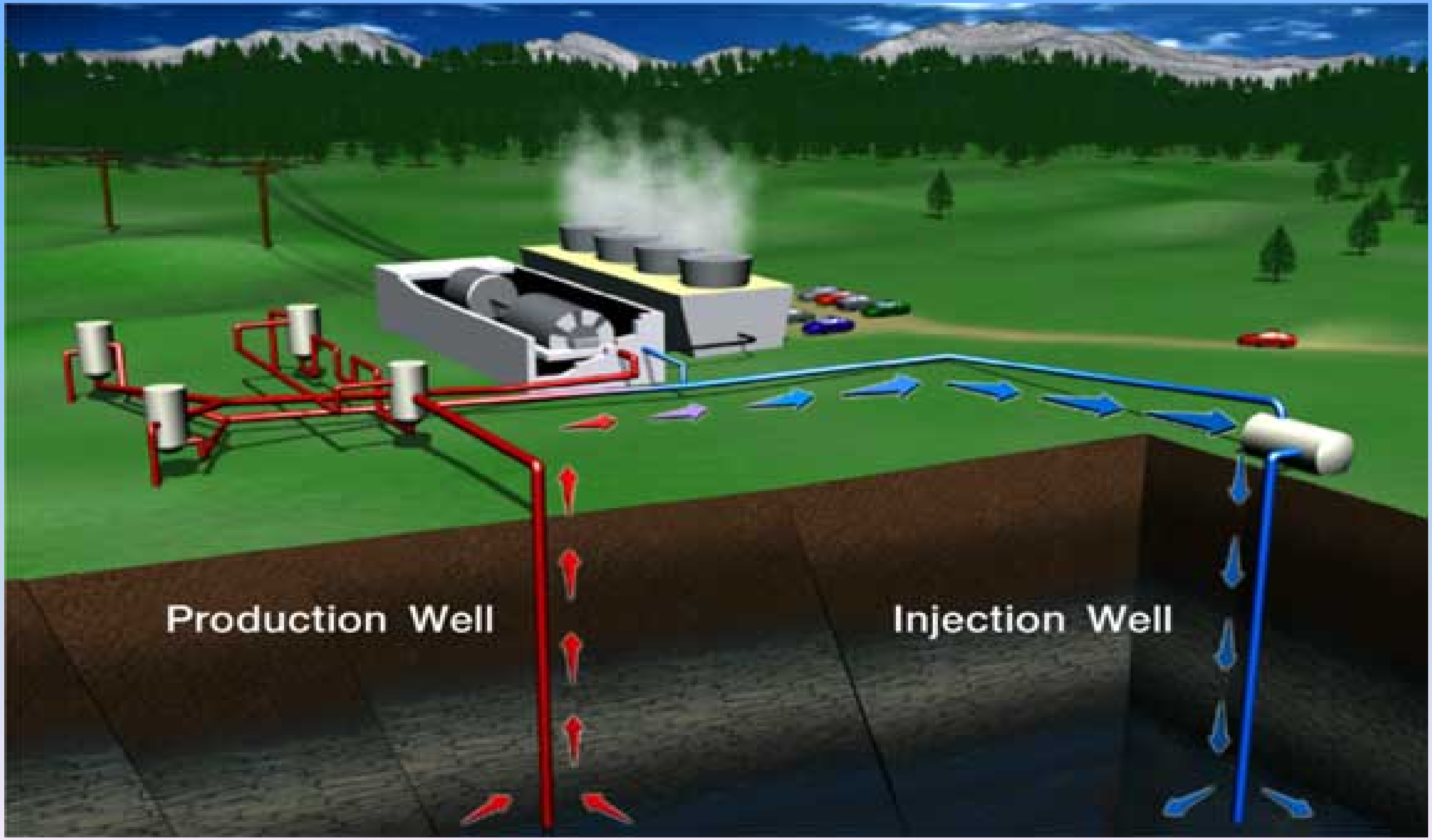



Geothermal Drilling at
Capitol Building,
Boise, Idaho

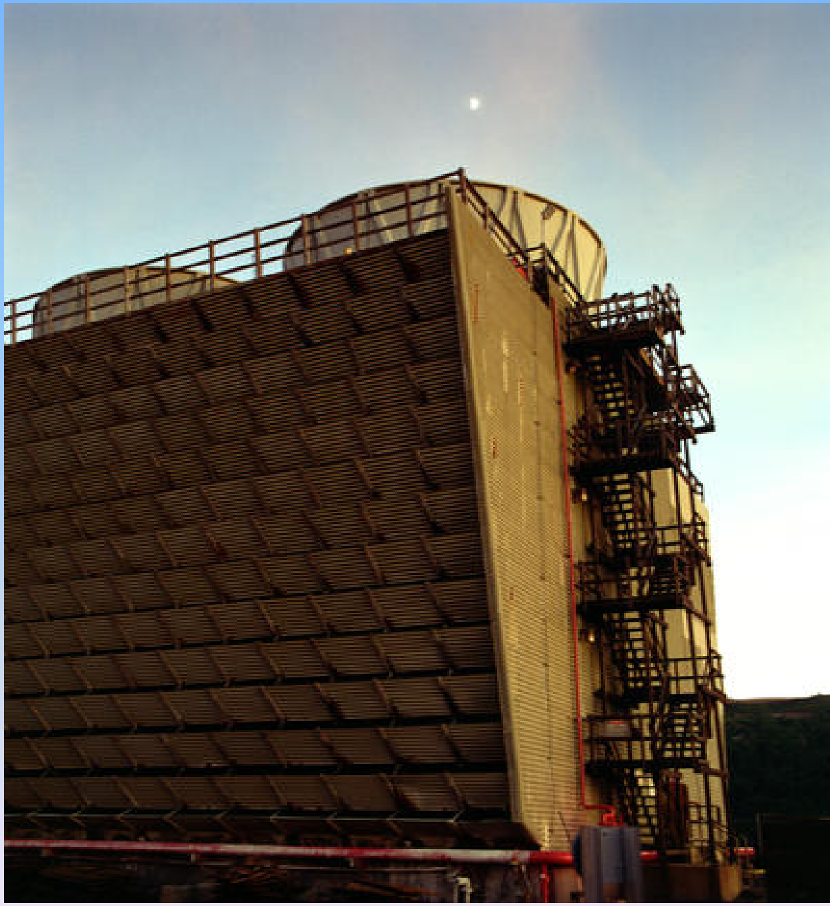
Types of Geothermal Utilization

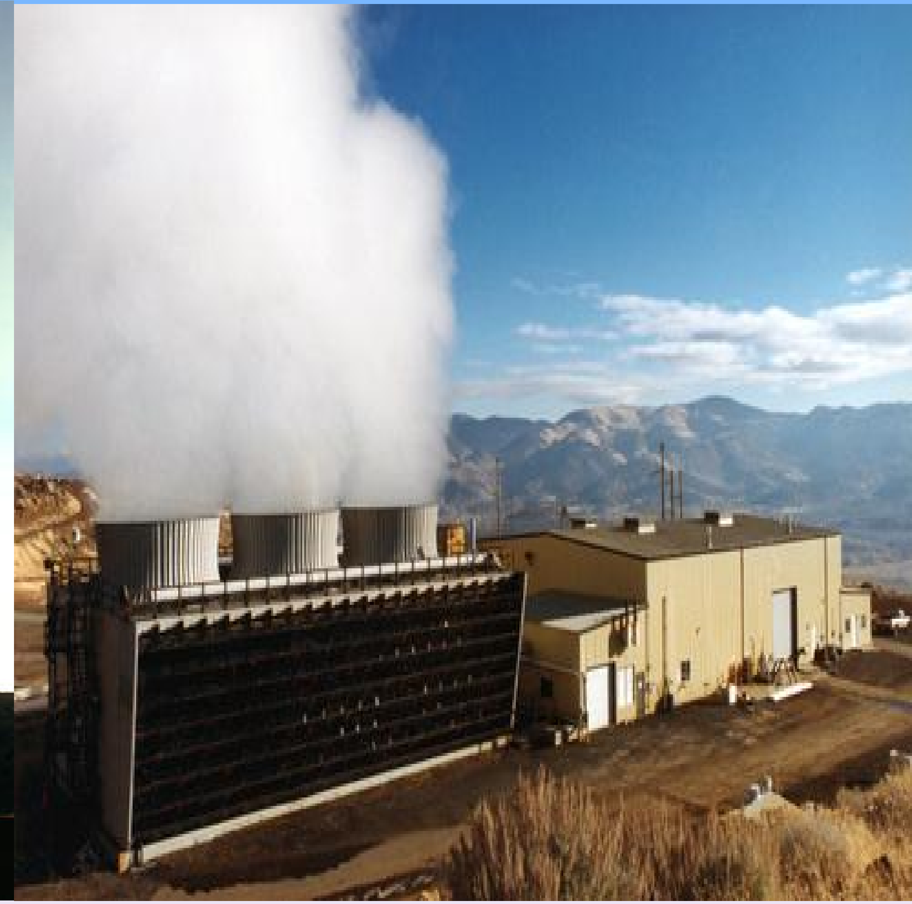
- Direct
  - Applicant filed
  - Can be issued non-competitively if no interest after 90 days
  - State, Tribal, or Local Governments use resource without sale and for public purposes other than commercial generation of electricity
- Indirect
  - Heat energy is used indirectly, most common is Electrical Generation
  - EPAct requires nominated tracts to first go through competitive process
  - After sale goes over the counter (retains configuration for 30 days)
- Provision for Mining Claims
  - Provision in EPAct
  - Allows mining claimants to obtain a non-competitive geothermal lease to avoid “top-filing”
  - Approved mining plan of operations

Flash Plant

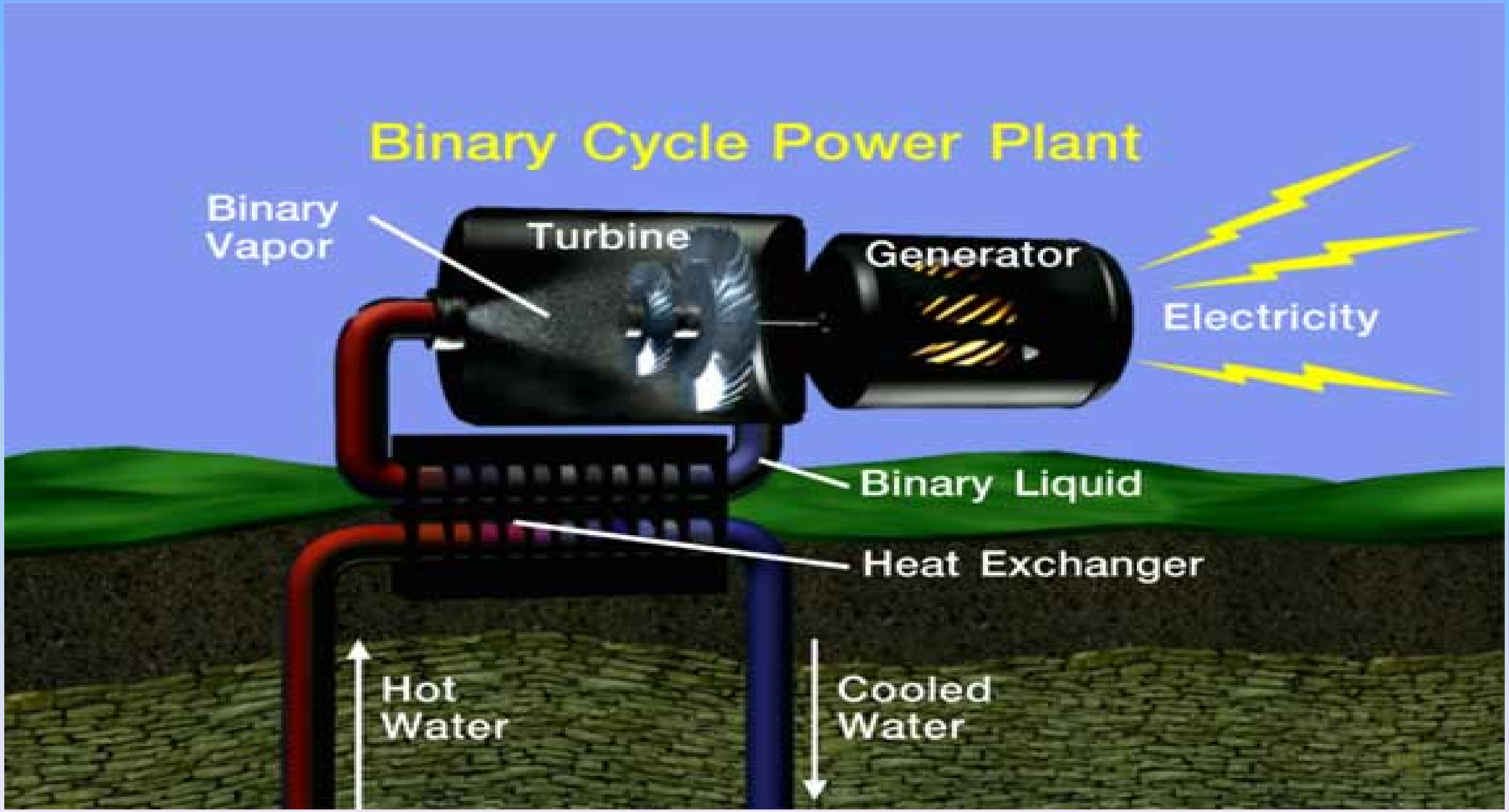


Water-cooled Condensers

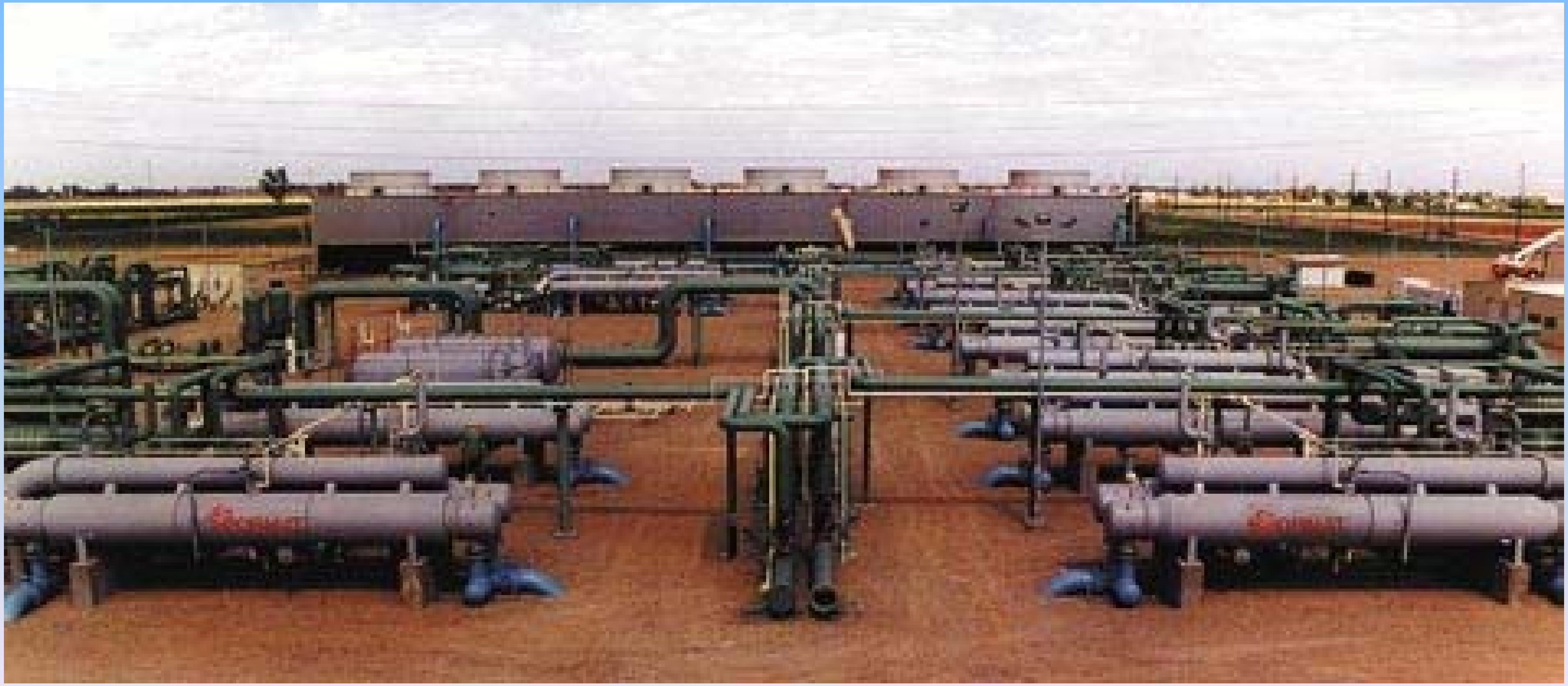




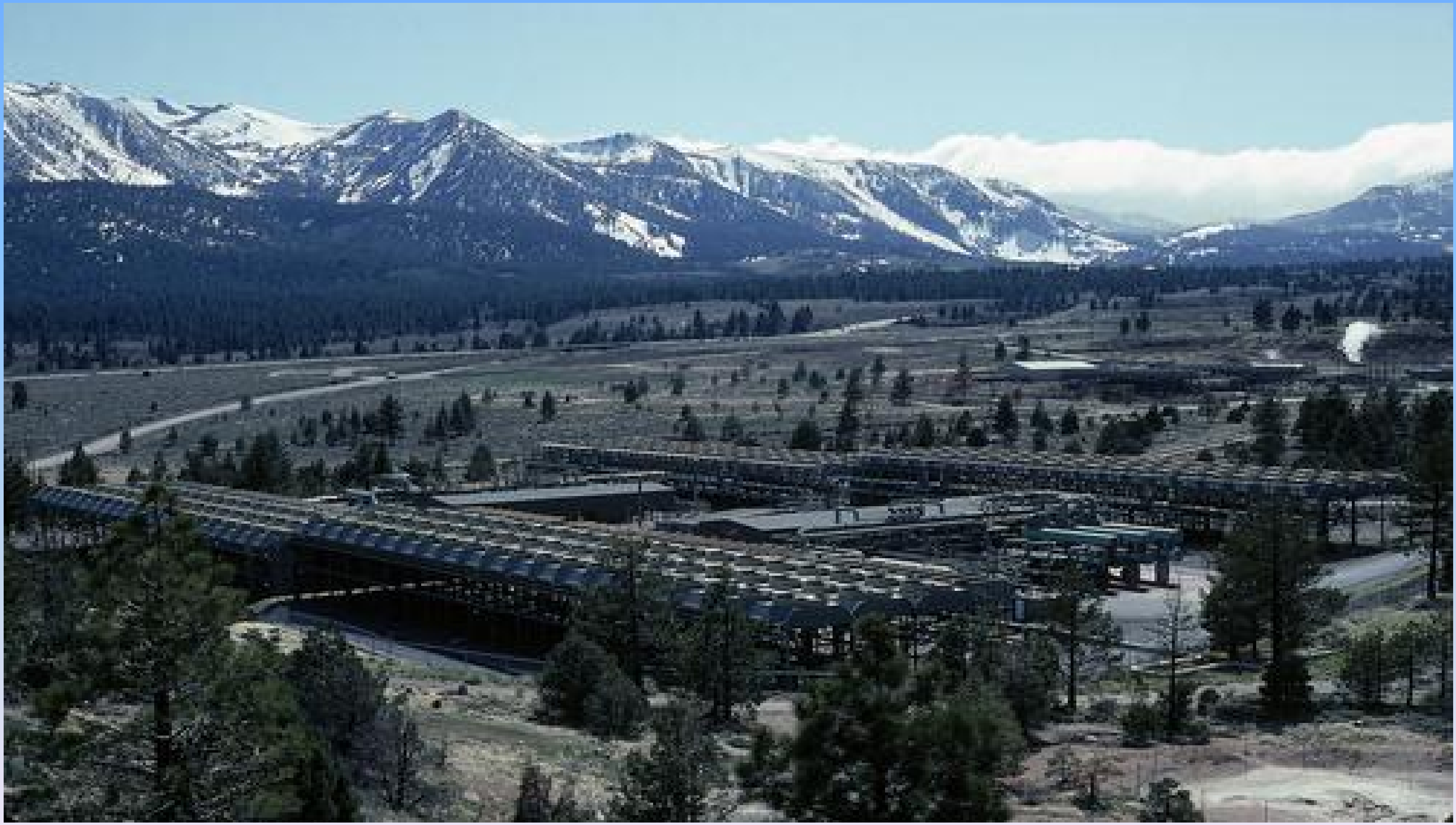
Binary Plant



Heber 40 MW Binary (Ormat)



Mammoth 140 MW Binary (Ormat)



Air Cooled – Binary - Steamboat

Typical Wellhead – Moderate Temp

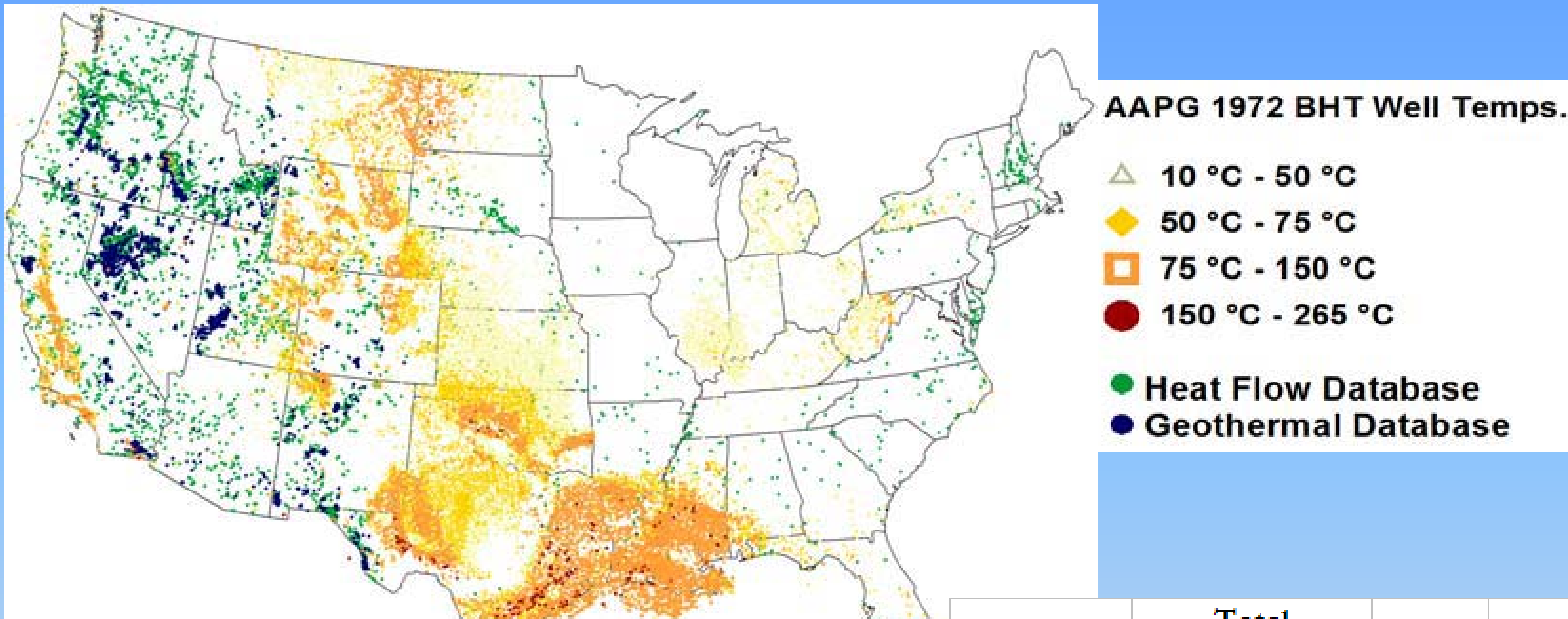
Expansion Loop – Soda Lake

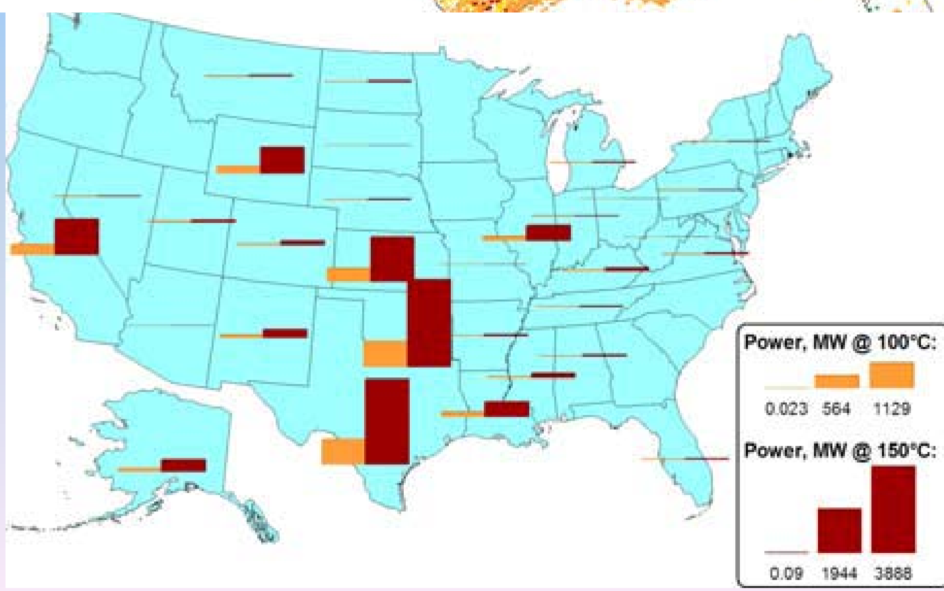
Chena Hot Springs, AK, Gains Distributed Generation Begins in 2006

- *Commissioned July, 2006*
- *1 system, 2nd unit in Dec 06*
- *Lowest geothermal temp in world <165'F*
- *Drivers: Off-Grid, sustainable geothermal power and heat, for multiple applications*

UTC Power
A United Technologies Company

SMU Estimated Co-Produced Geothermal Potential



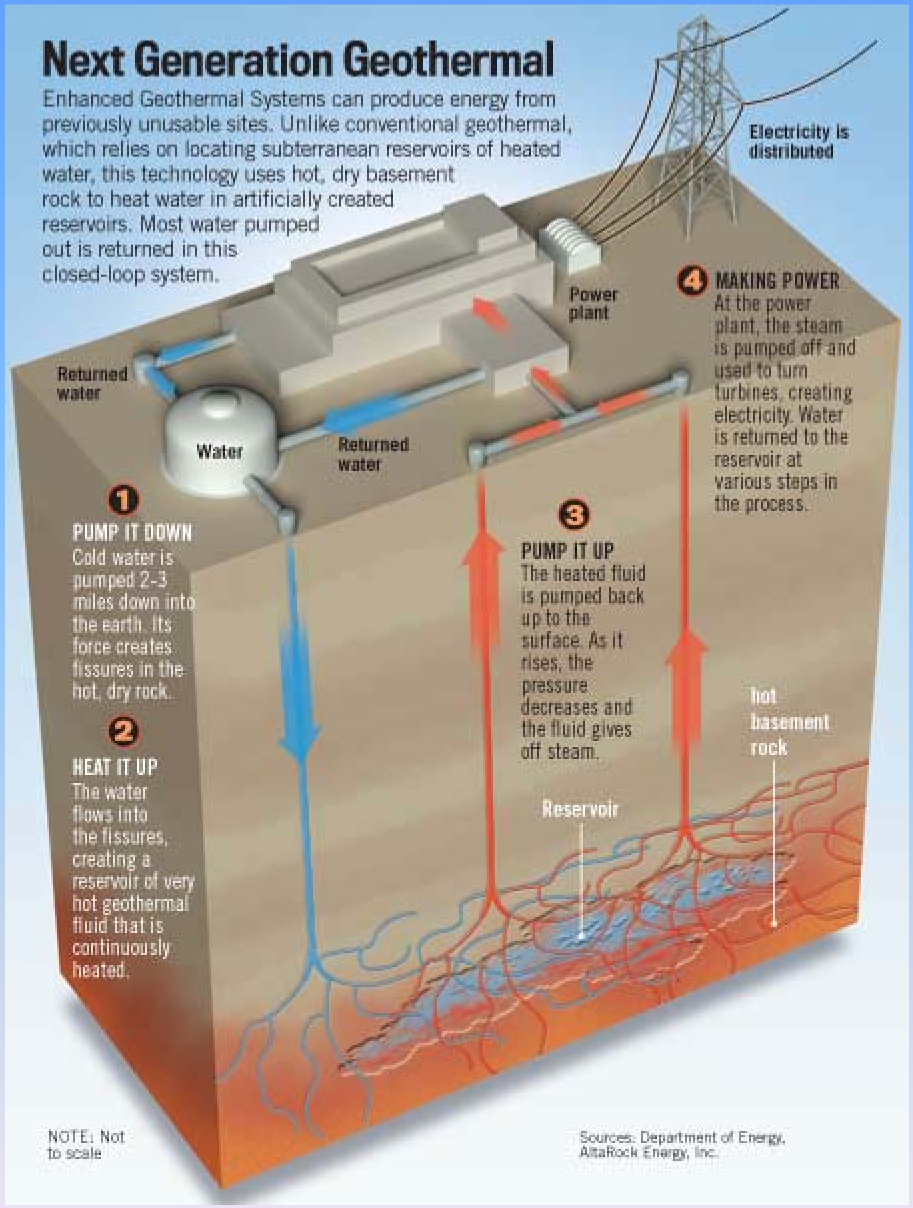


State	Total Processed Water, 2004 (bbl)	Power, MW @ 100°C	Power, MW @ 140°C	Power, MW @ 180°C
Alabama	203,223,404	18	47	88
Arkansas	258,095,372	23	59	112
California	5,080,065,058	462	1169	2205
Florida	160,412,148	15	37	70
Louisiana	2,136,572,640	194	492	928
Mississippi	592,517,602	54	136	257
Oklahoma	12,423,264,300	1129	2860	5393
Texas	12,097,990,120	1099	2785	5252
Totals	**32,952,140,644**	**2,994**	**7,585**	**14,305**

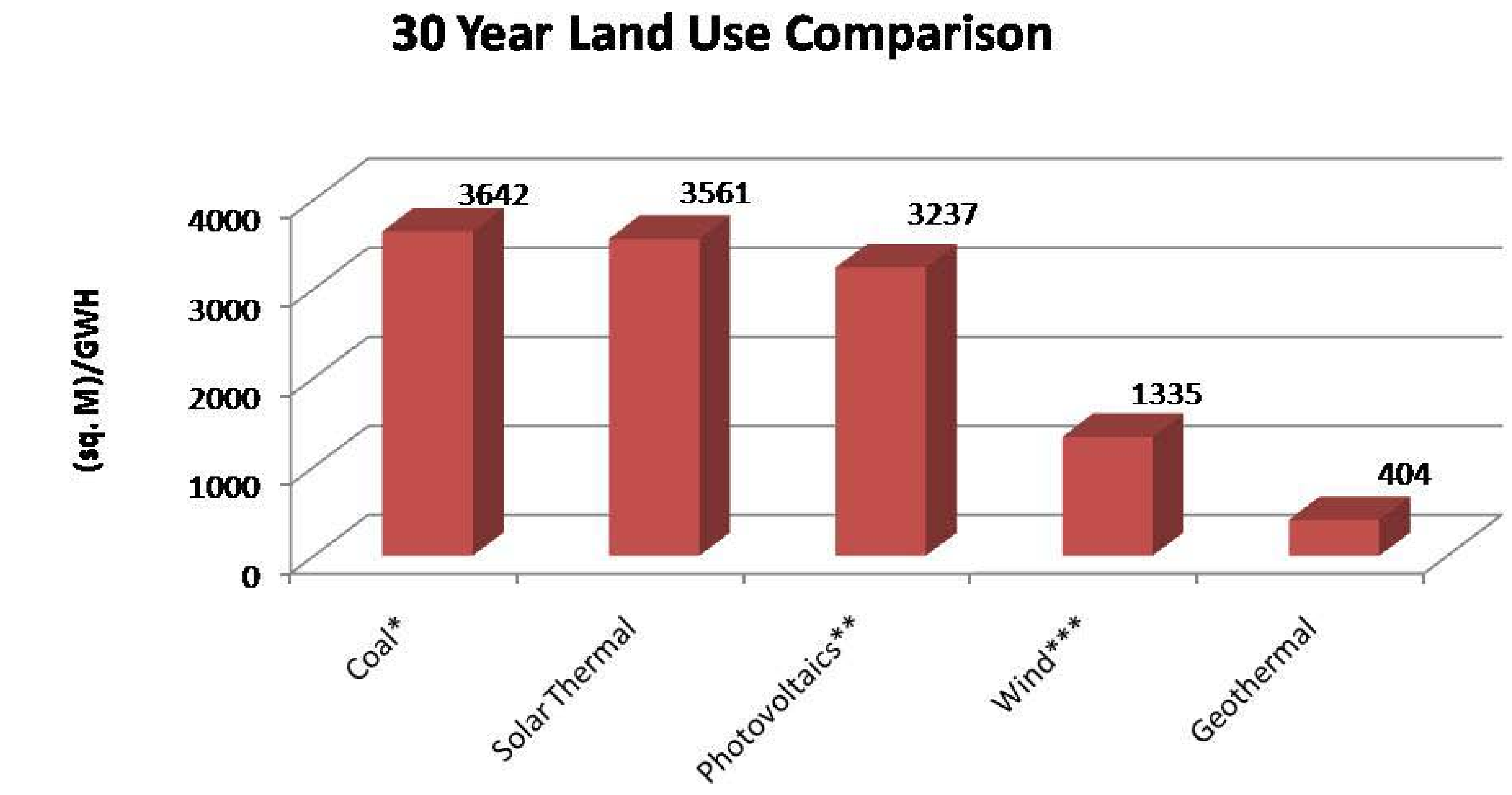
Geopressured Demonstration Plant in Texas

Co-production geothermal fluids: Usable geothermal fluids are often found in oil and gas production fields. The Southern Methodist University Geothermal Energy Program has identified thousands of megawatts of potential energy production from hot water being coproduced with oil and gas. There are presently two geothermal co-production demonstrations underway supported by the U.S. DOE, at the Rocky Mountain Oil Test Center in Wyoming and the Jay oil field in Florida (GEA, 2008).

Engineered Geothermal Systems (EGS)
The Energy Under Our Feet



EGS projects produce electricity using heat extracted with engineered fluid-flow paths in hot rocks. These pathways are developed by stimulating them with cold water injected into a well at high pressure (Altra Rock Energy)

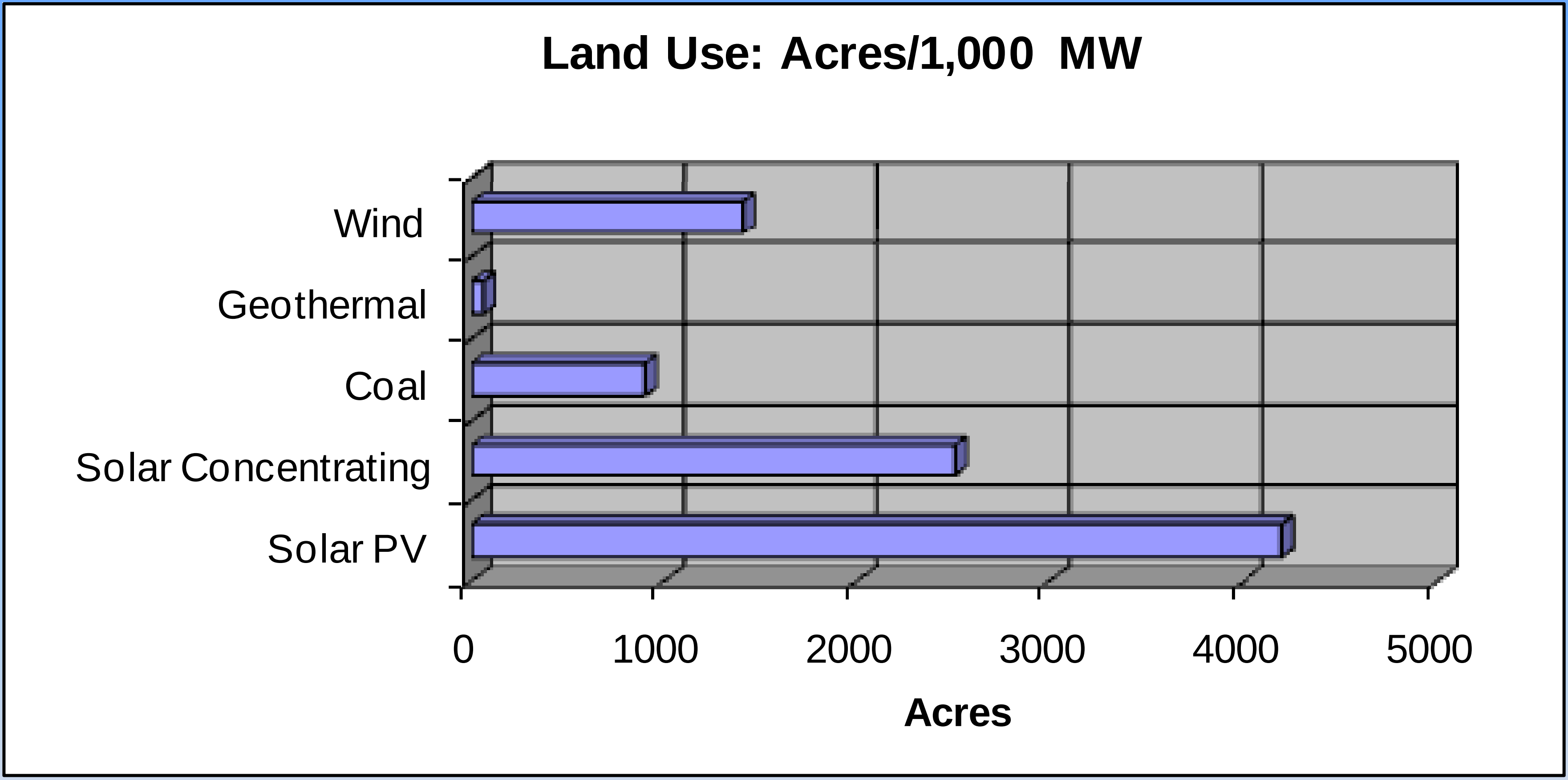


*Includes mining.

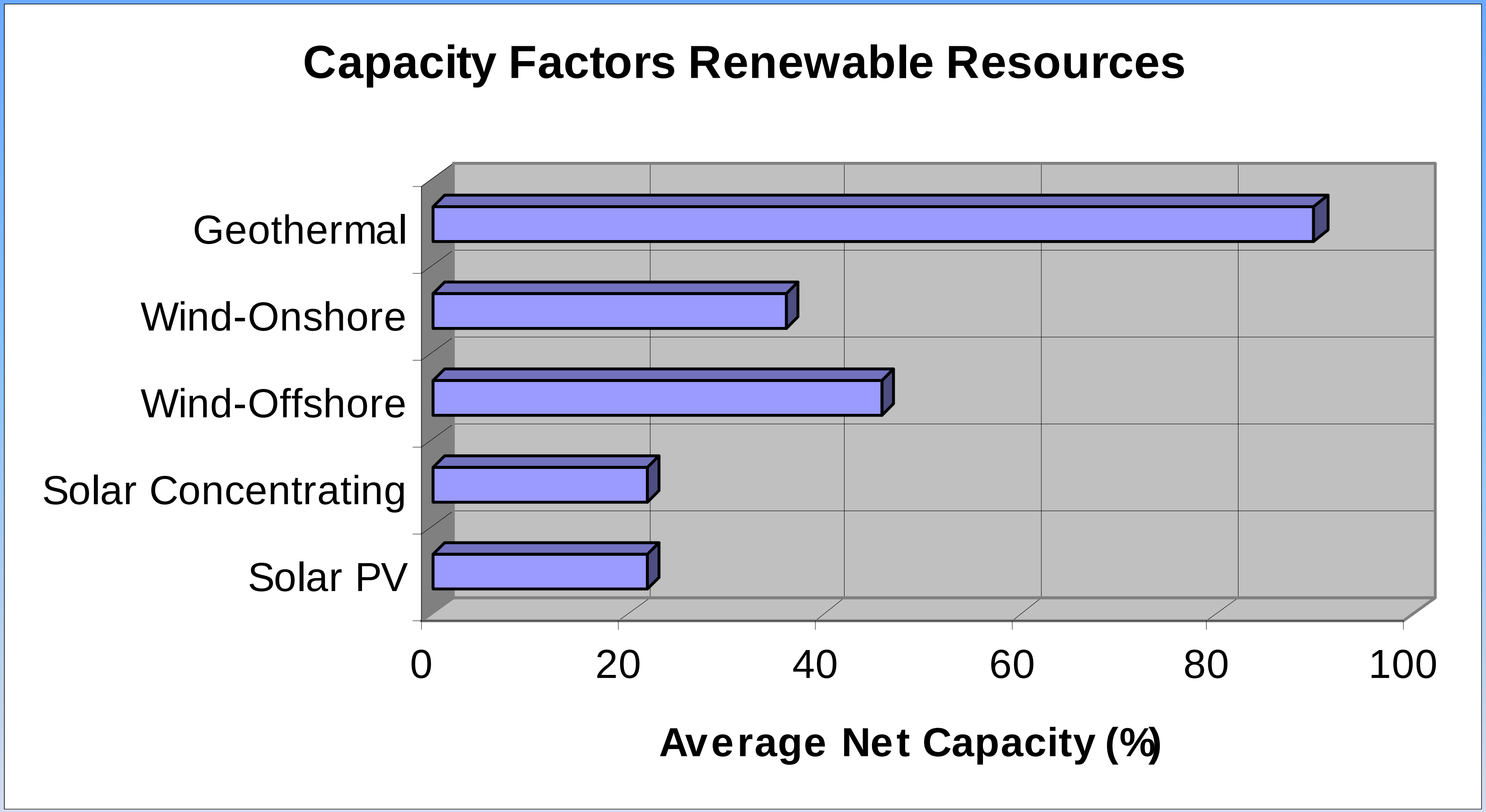
**Assumes central station photovaltaic project.

***Land actually occupied by turbines and service roads.

Source: GEA

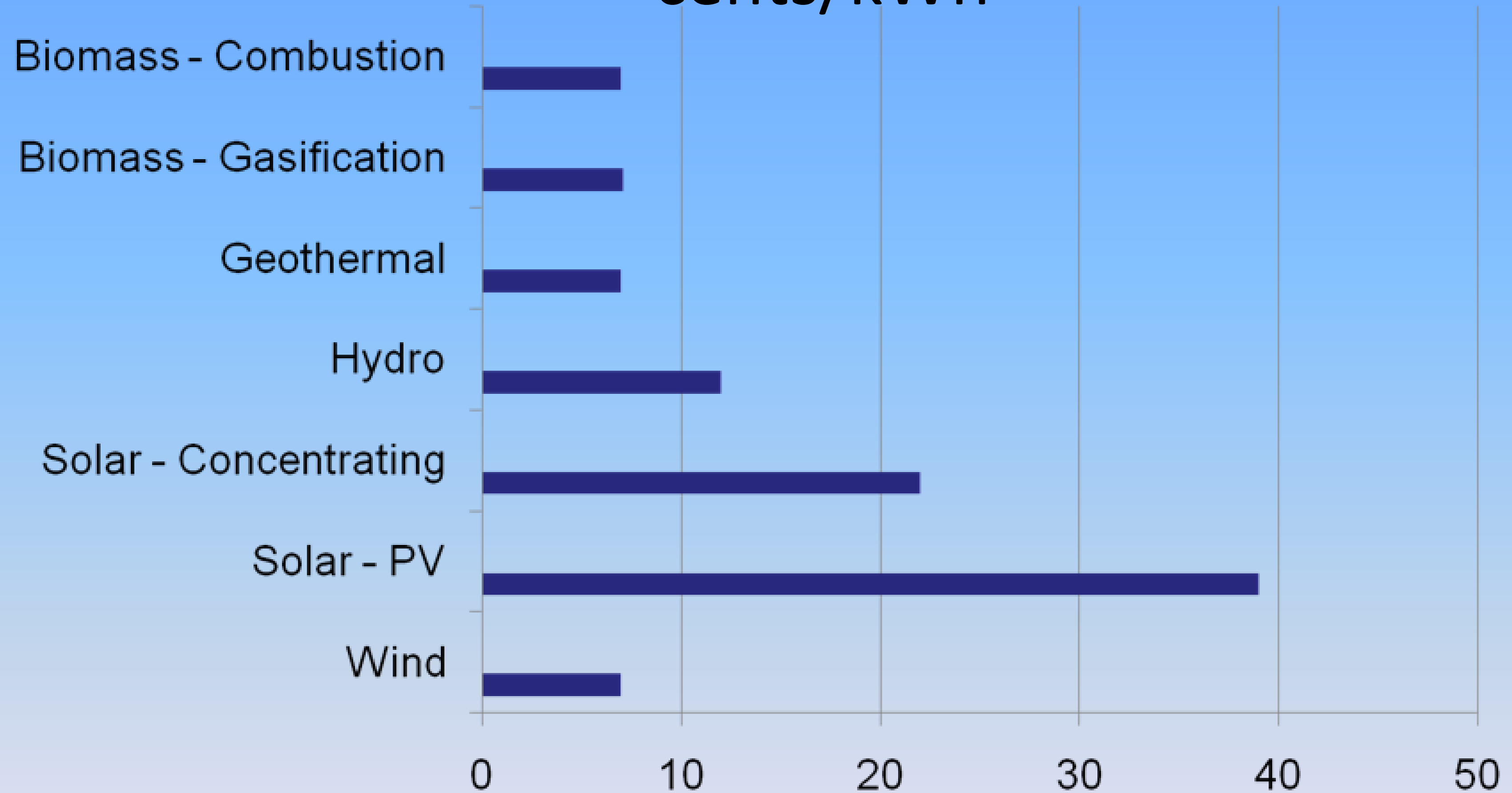


Source: National Renewable Energy Laboratory and Glitner Bank



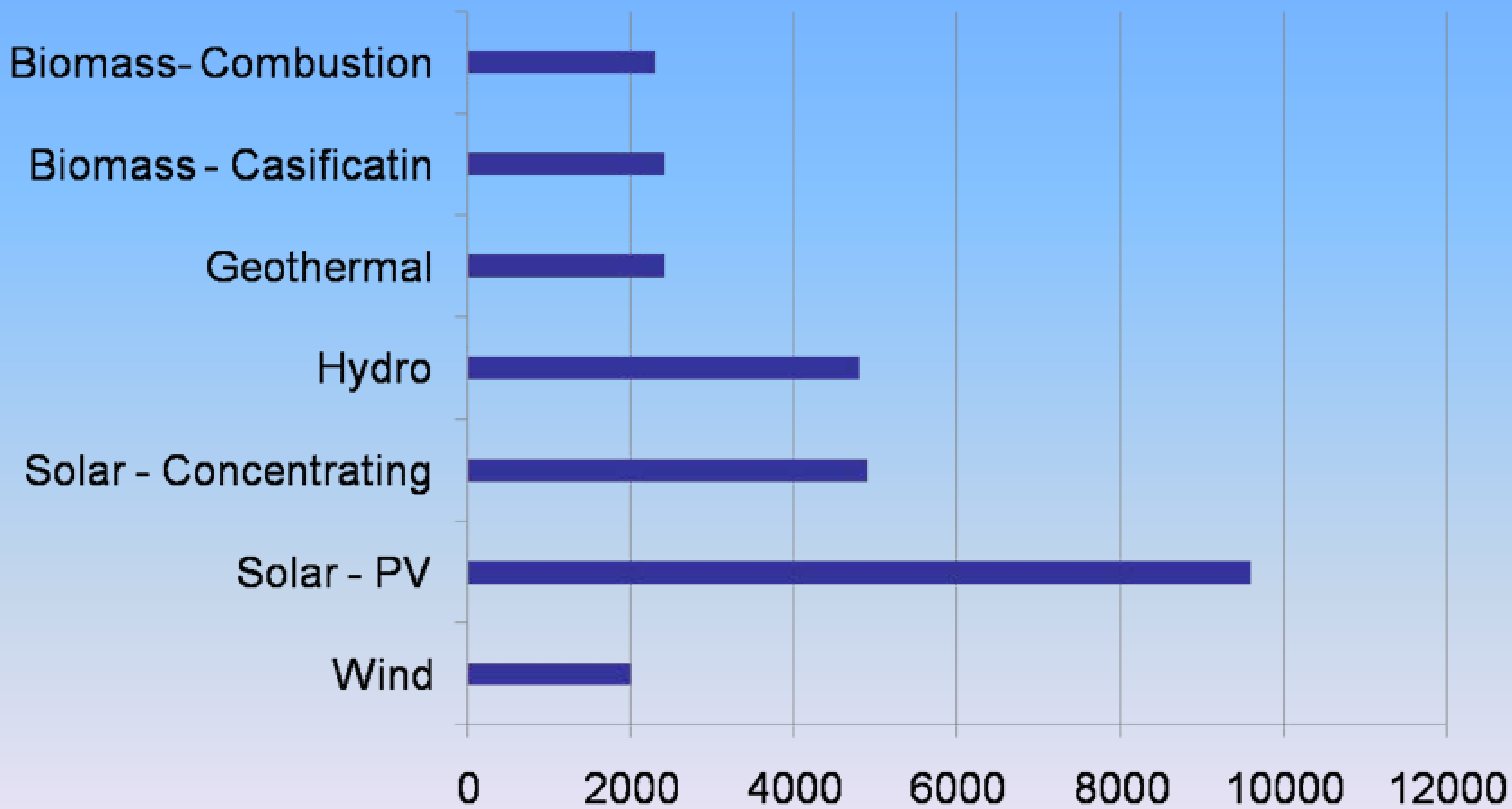
Source: Glitner Bank

Cost of Electricity cents/kWh



Source: California Energy Commission and Glitner Bank

Installed Cost for Electricity Generation
$ ‘000/MW



Source: California Energy Commission and Glitner Bank

Economics: 20 MW_{net} Project

1. Exploration & resource assessment — $ 7.0 M
    1. 12 Months time frame
2. Well field drilling and development (12 wells) — $20.0 M
    1. 12 Months after #1
3. Power plant, surface facilities& transmission — $35.0 M
    1. 18 Months with overlap with #2
4. Financing, "soft costs" — $ 8.0 M
    1. Financing Commitment Fees;
    2. Legal, Accounting & Consulting fees;
    3. Interest during construction;
    4. Debt service & operating reserve; and
    5. Project contingencies & Development Fee
    6. 12 Month process begins after completion of #1

- TOTAL FINANCED COST — $70.0 M
- TOTAL AVERAGE DEVELOPMENT PERIOD — 36 MONTHS
    - Plus approximately 12 months to acquire federal of private lease control

Source: ORMAT

Future View - IMHO

- Obama Administration supports renewable energy
  - Obama-Biden comprehensive New Energy for America Plan:

    "Ensure 10% of our electricity comes from renewable sources by 2012, and 25% by 2025"
  - PTC Extension through 2013 in Economic Stimulus Package
  - EO 13212, *Actions to Expedite Energy-Related Projects*
  - Secretarial Order 3283, Enhancing Renewable Energy Development on the Public Lands
    - Established Renewable Energy Coordination Offices to expedite renewable projects
- Geothermal is Hot !!

Acknowledgements

Thanks to the BLM staff for their assistance in preparation of this presentation

Any questions?