

Geothermal Energy: An Overview

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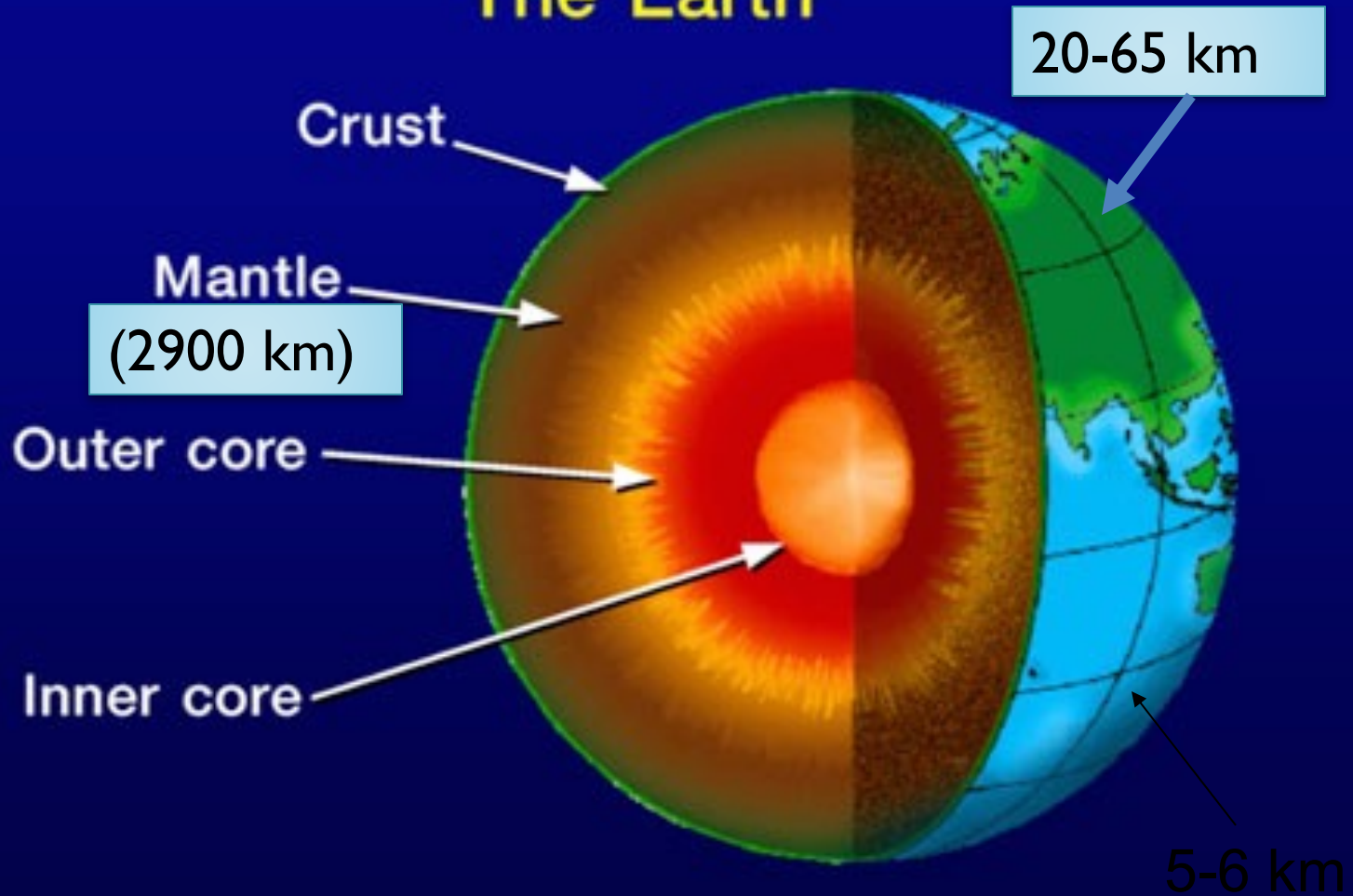




Points to be covered

- The deep earth as a thermal source
- Direct uses of geothermal energy
- Types of geothermal electrical generation
- Benefits of geothermal power generation
- Current levels of electrical generation capacity worldwide
- Issues regarding geothermal

The Earth



Temperature and depth

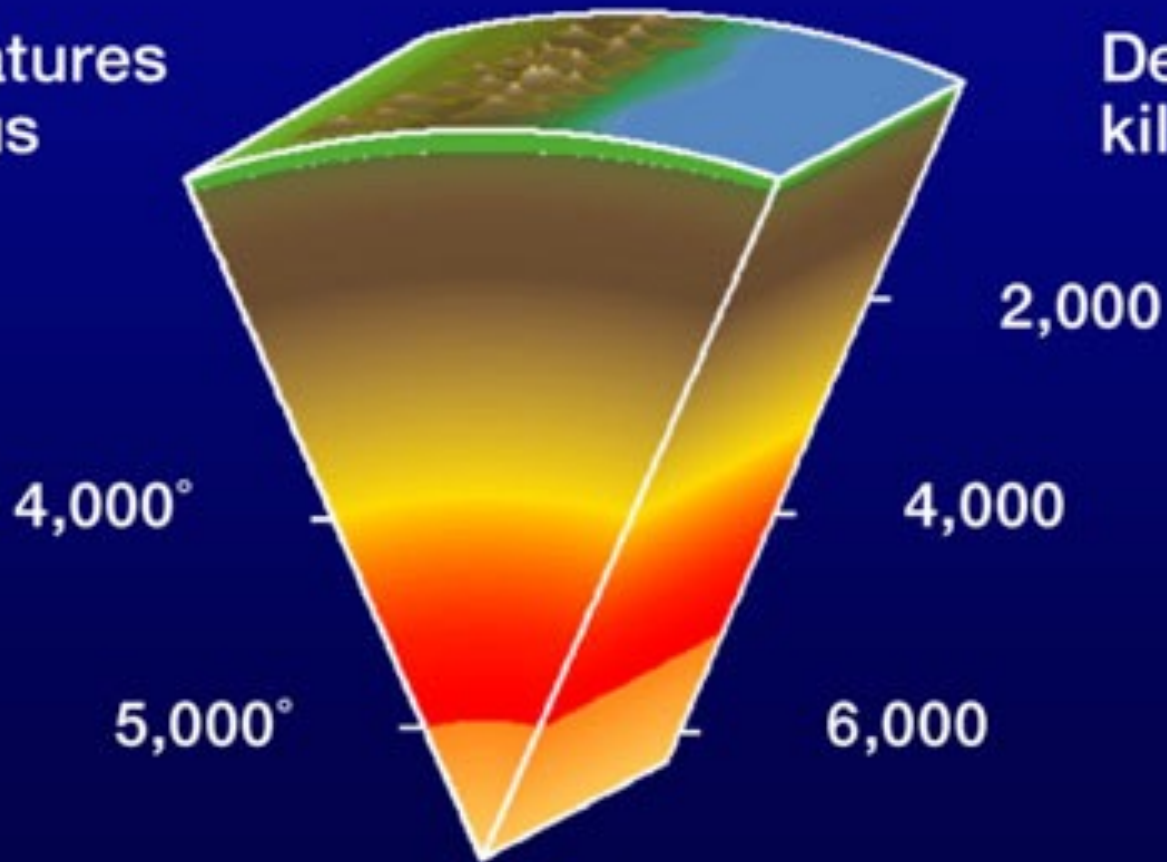
- Average gradient:
 - $2.5 - 3.0^{\circ}\text{C} / 100\text{m}$
- Variation:
 - $1.0 - 25^{\circ}\text{C} / 100\text{m}$
- So if assuming average, temps at depth will be:

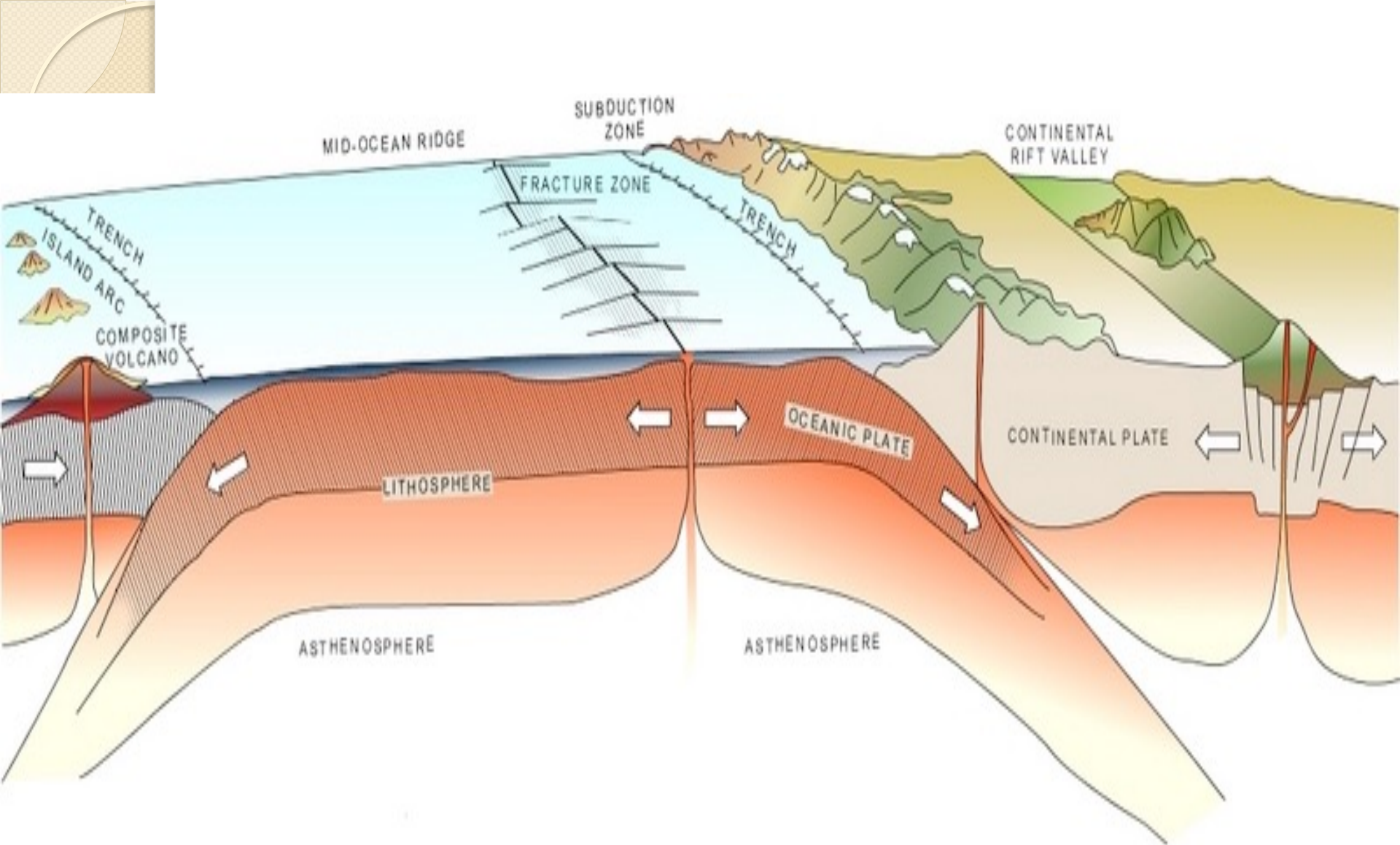
0 m	15°C
2000 m	70°C
4000 m	120°C

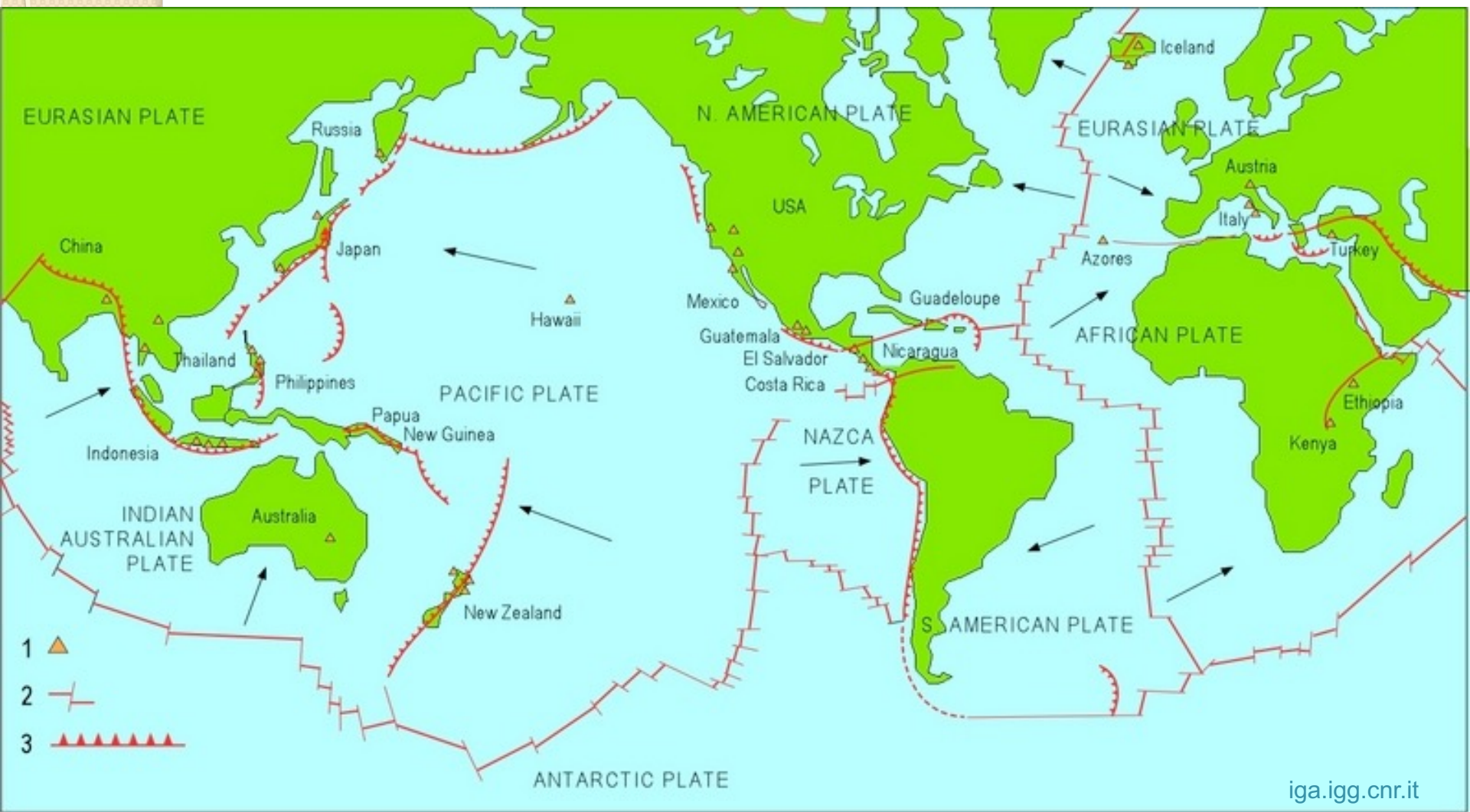
Temperatures in the Earth

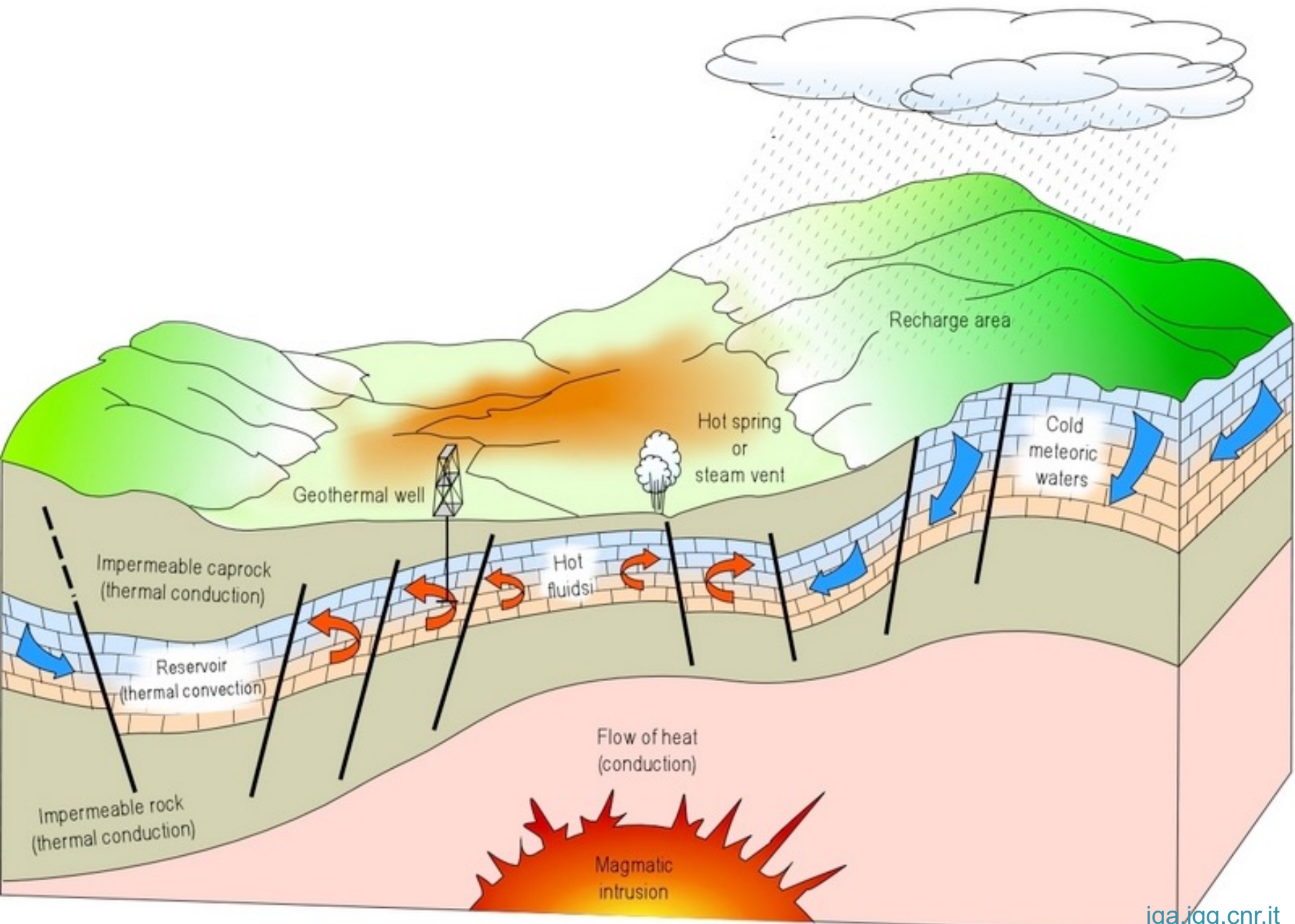
Temperatures
in Celsius

Depth in
kilometers









Geothermal energy is used in two ways

Direct



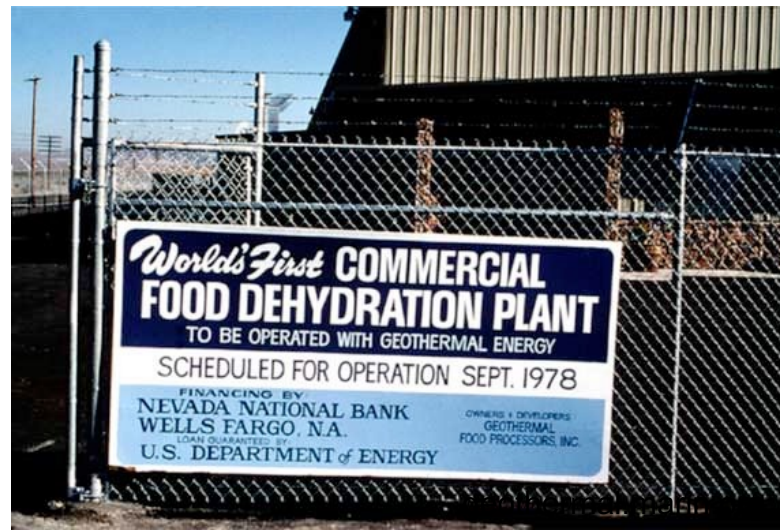
www.coloradodirectory.com/cottonwoodhotsprings/

Electrical generation



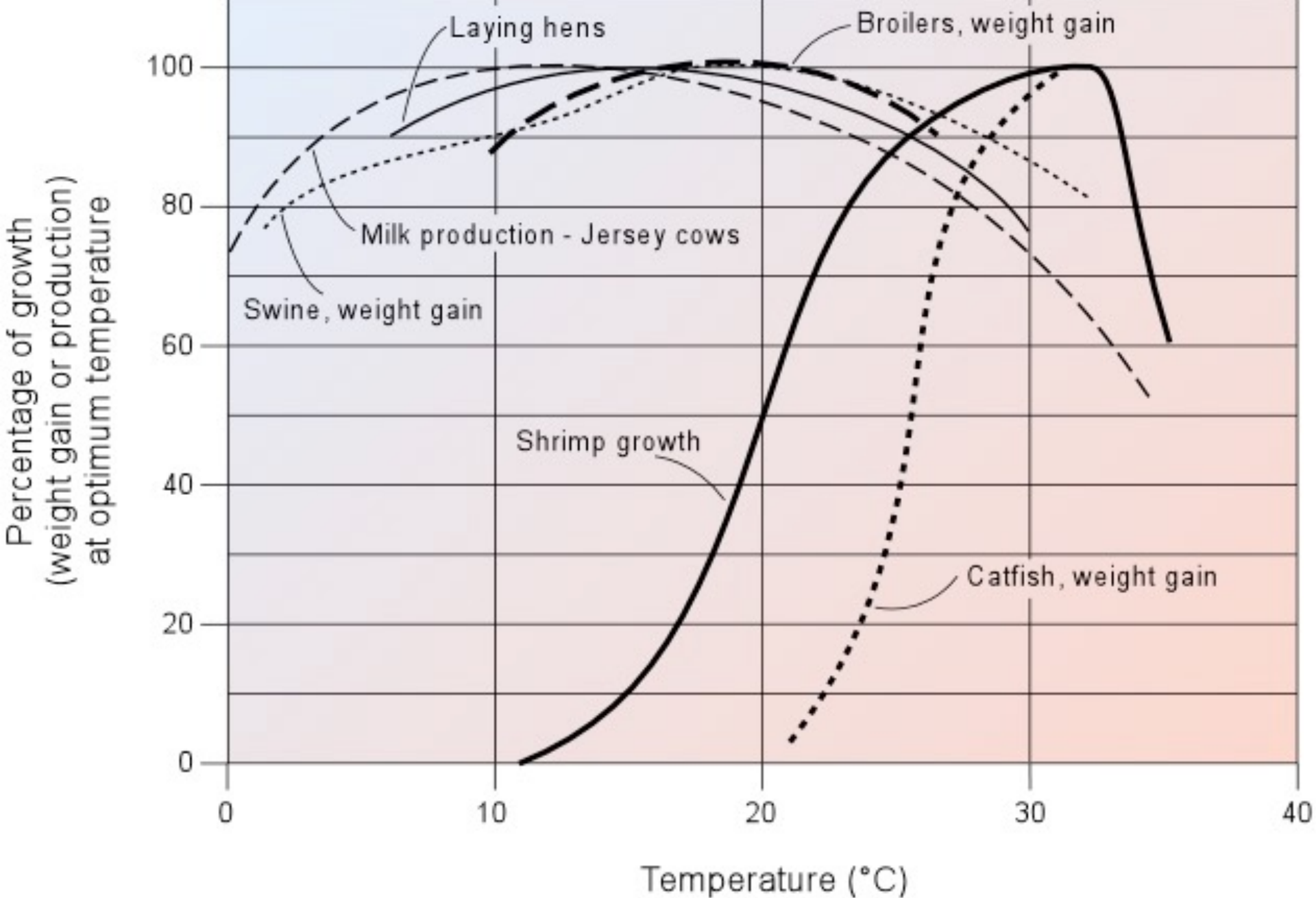
www.energywhiz.com

Direct uses of geothermal energy



Temperature (°C) 0 20 40 60 80 100 120 140 200 350

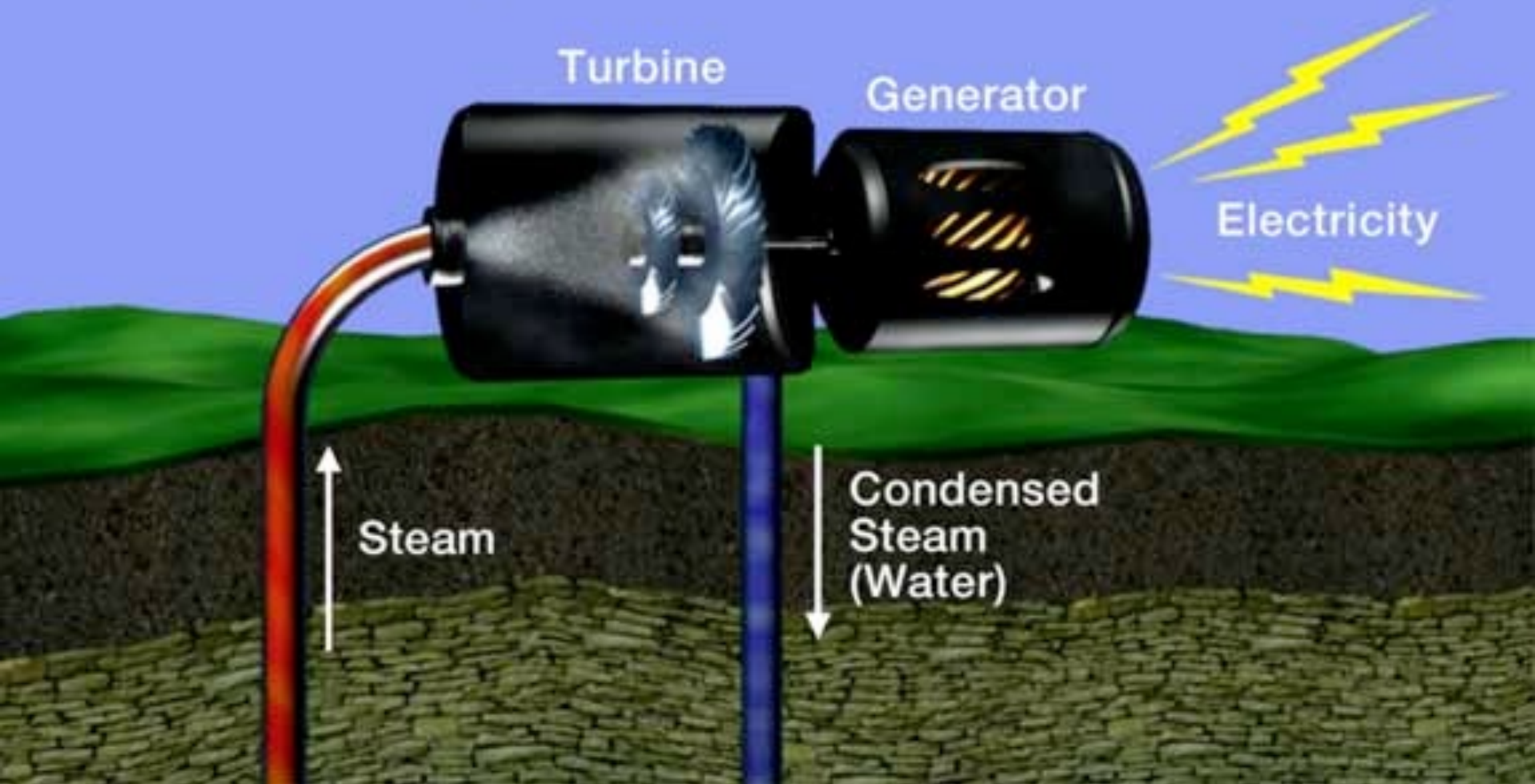




Types of geothermal electrical generation

- Dry steam
- Flash steam
- Binary cycle

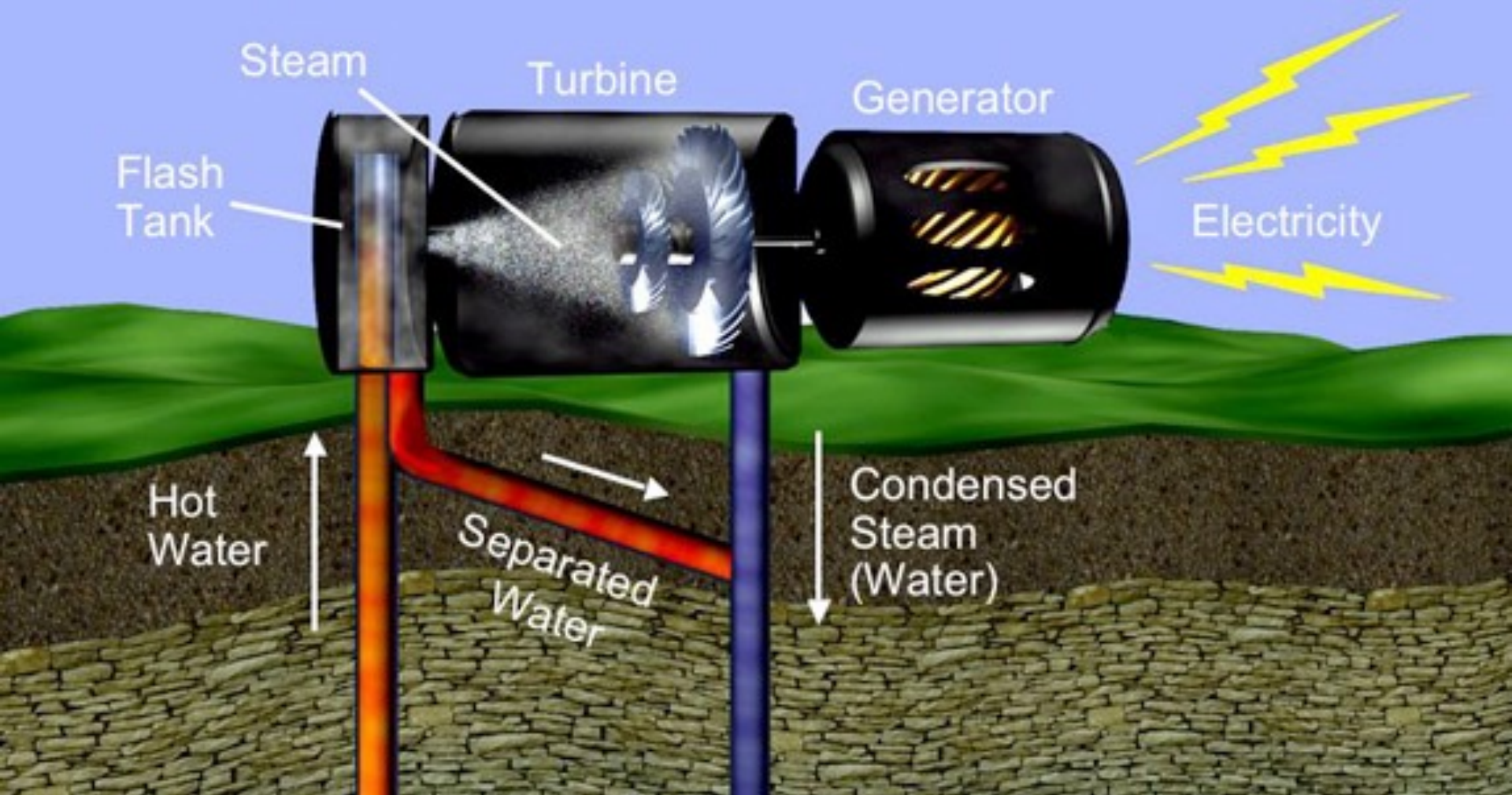
Dry Steam Power Plant



Geysers dry steam field in northern California



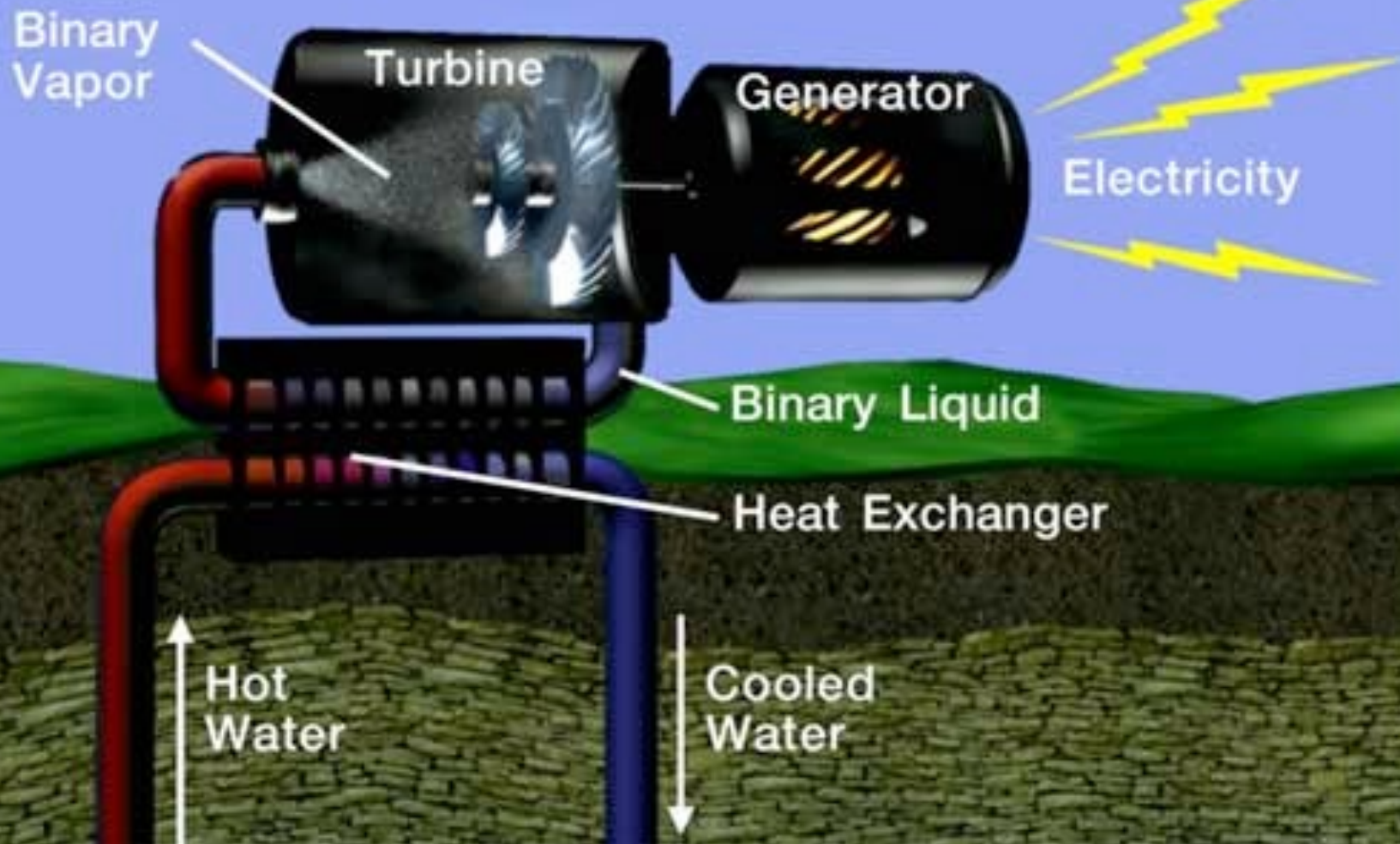
Flash Steam Power Plant



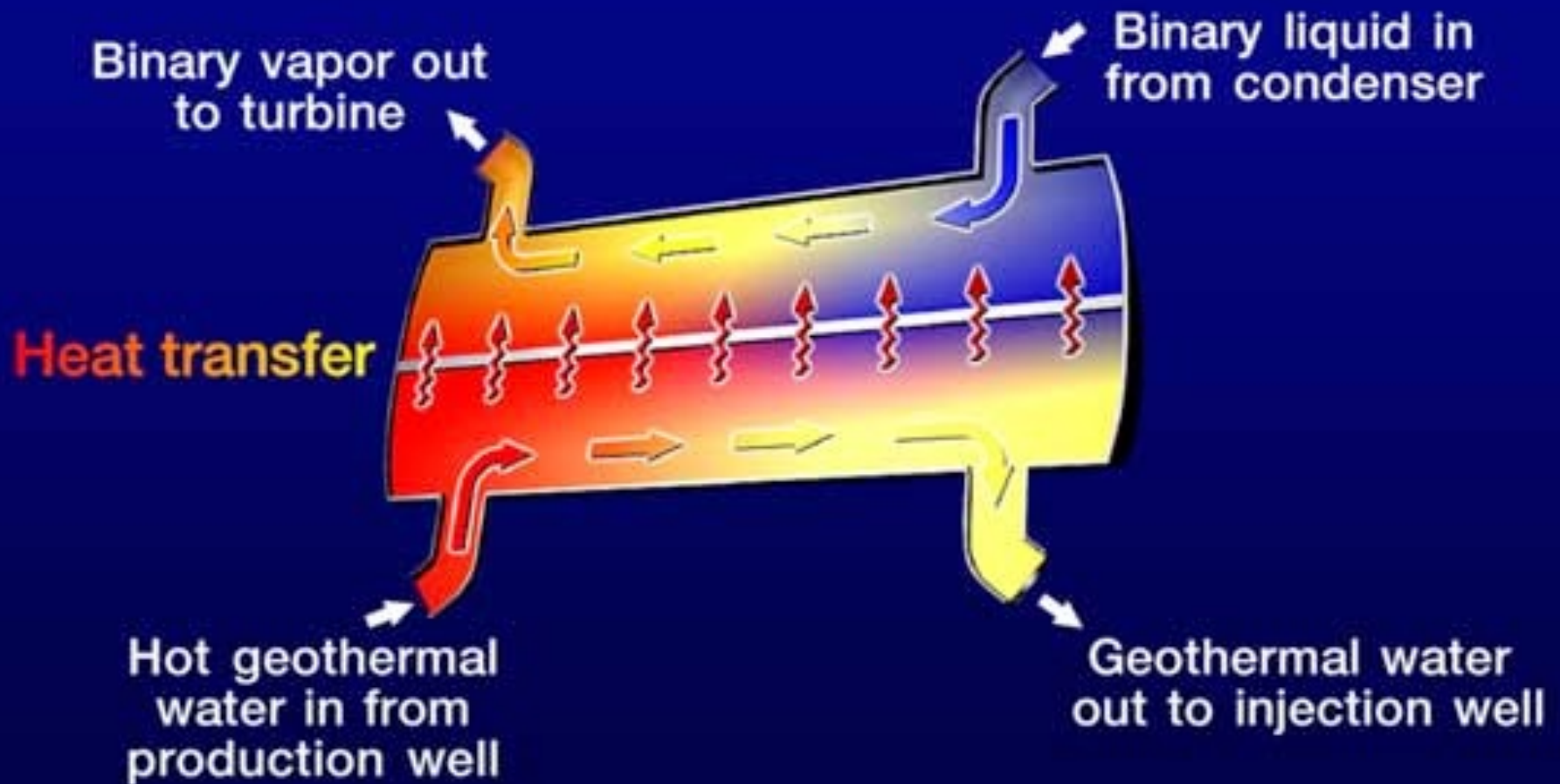
Flash steam plant in Japan



Binary Cycle Power Plant



Binary Power Plant Heat Exchanger



Binary plant in Nevada



Benefits of geothermal power

- Provides safe and reliable power with little land consumption
- Renewable and sustainable
- Provides constant baseload power
- Conserves fossil fuels
- Benefits local economies
- Can be implemented remotely
- Can prevent pollution caused by fossil fuels

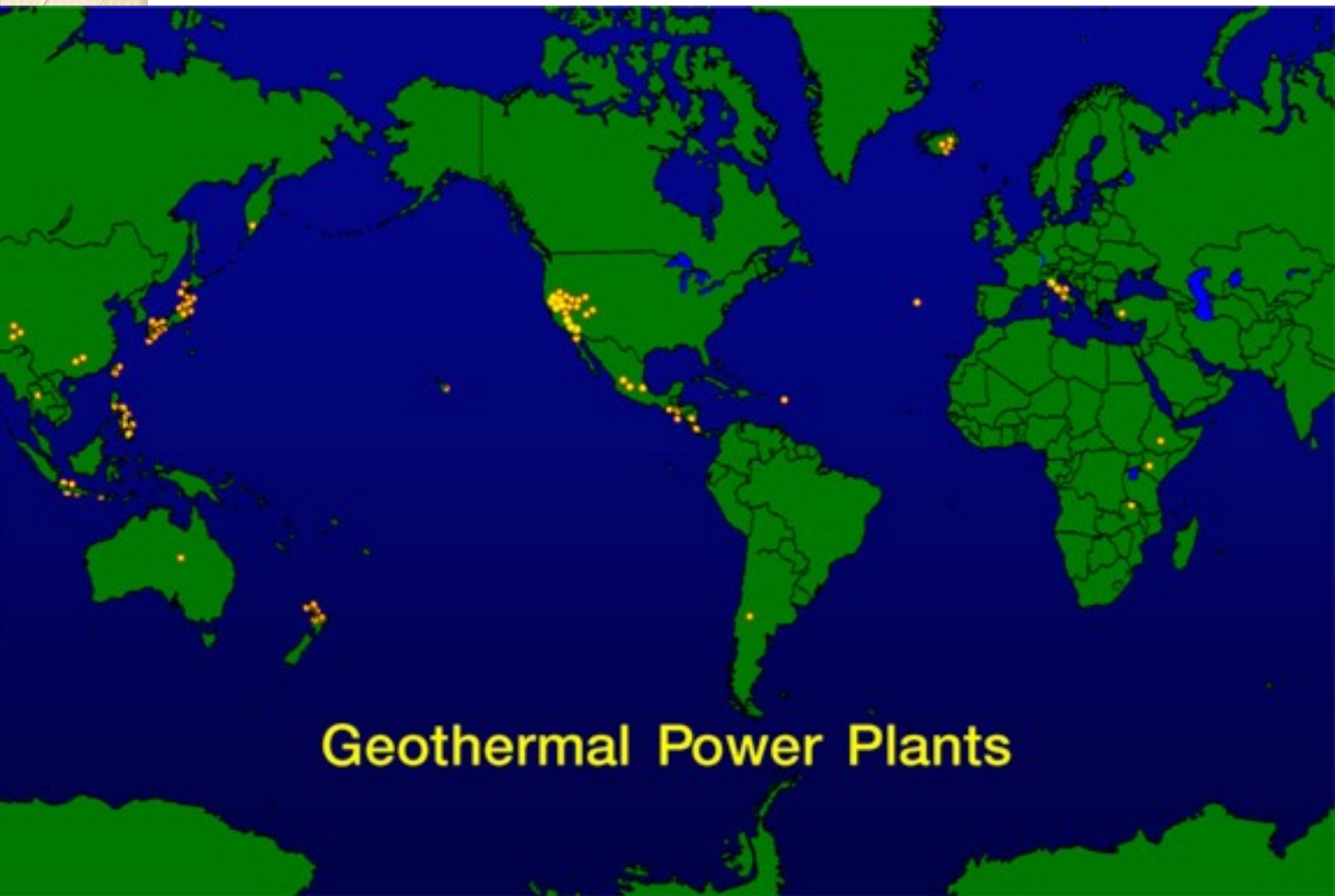
1932



2000

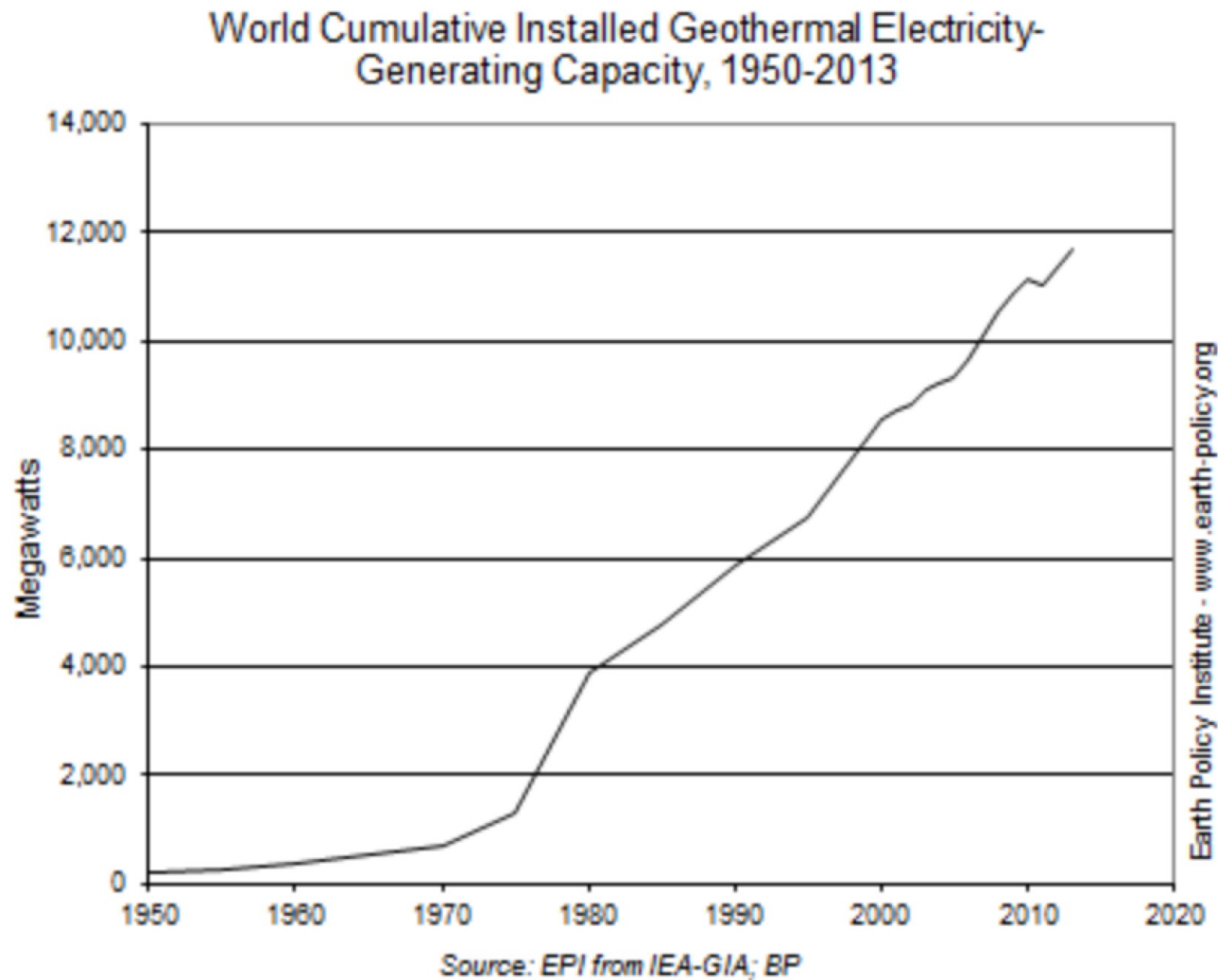


Reykjavik Using Geothermal

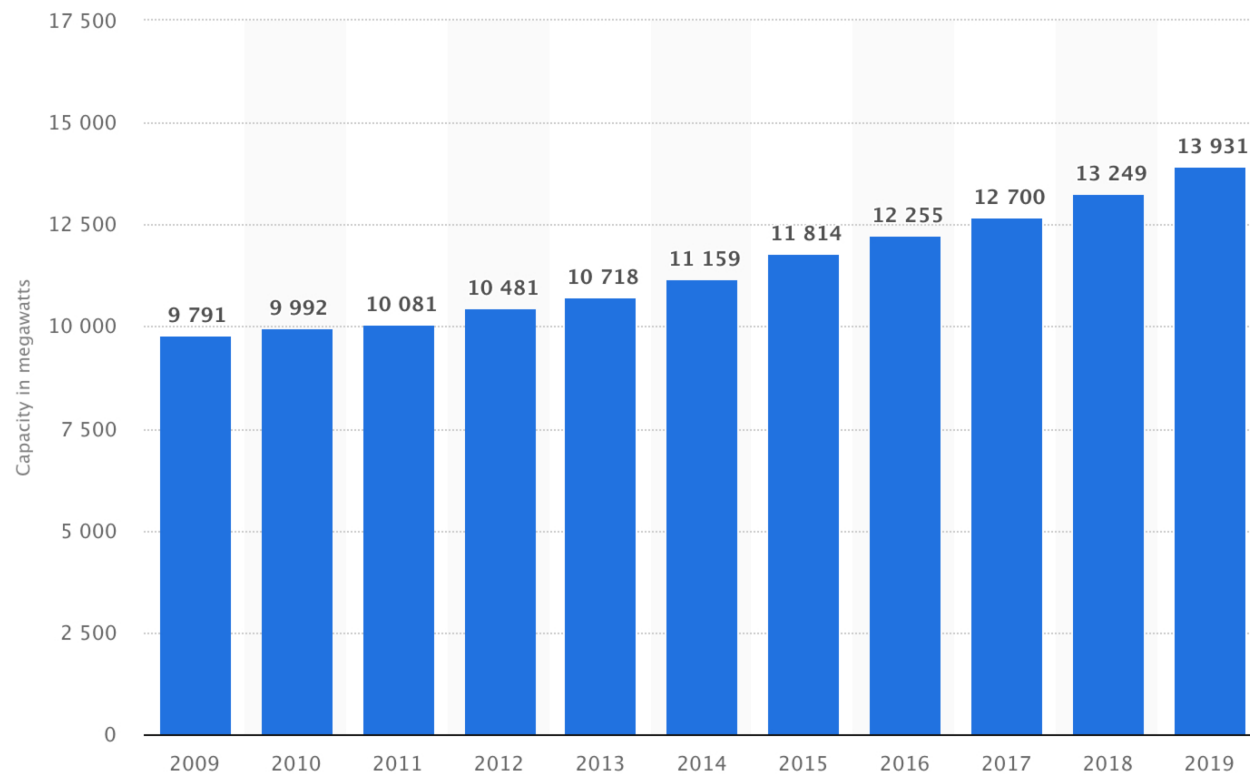


Geothermal Power Plants

Global Increase in Geothermal 1950-2015



Global increase in geothermal (2009-2019)

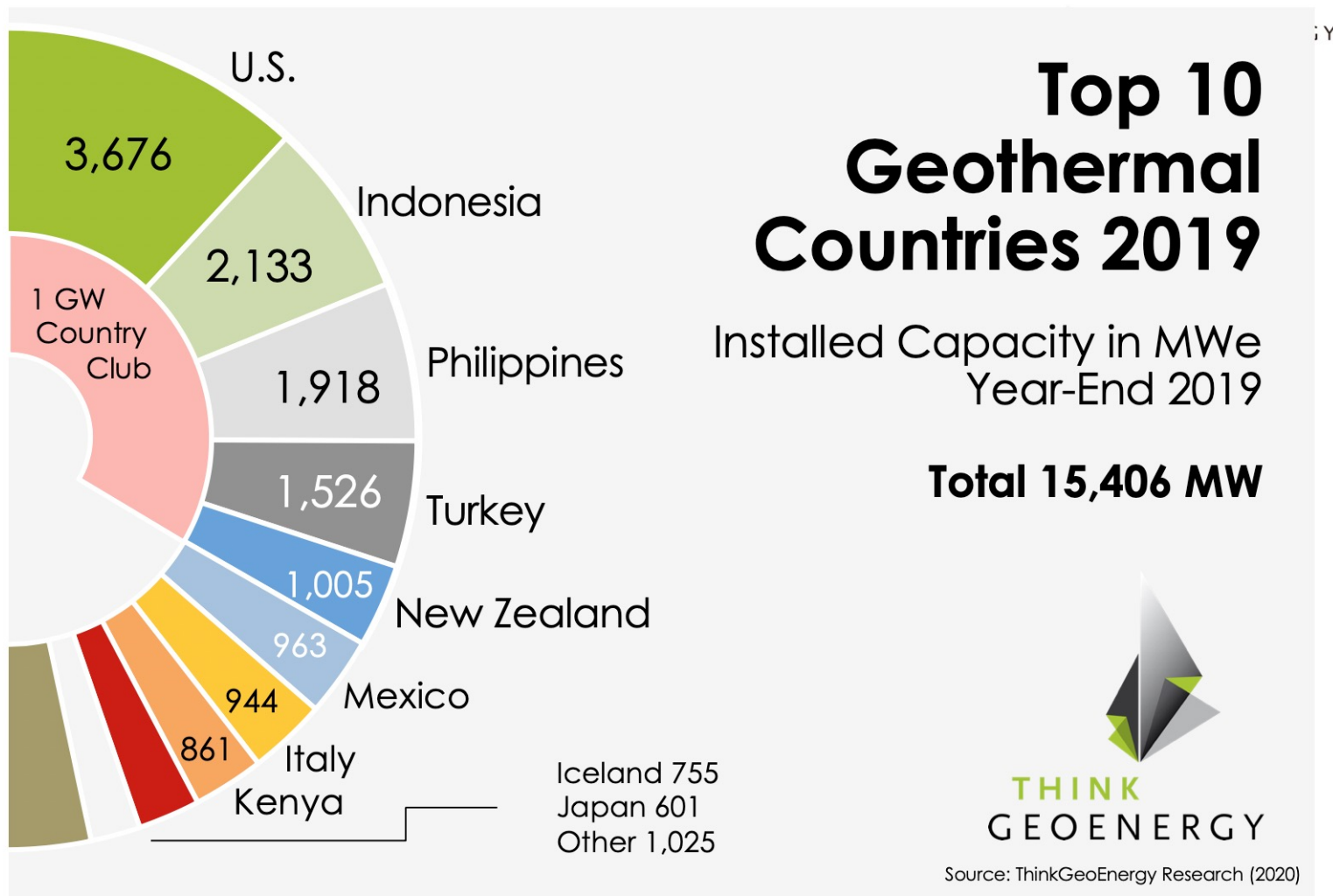


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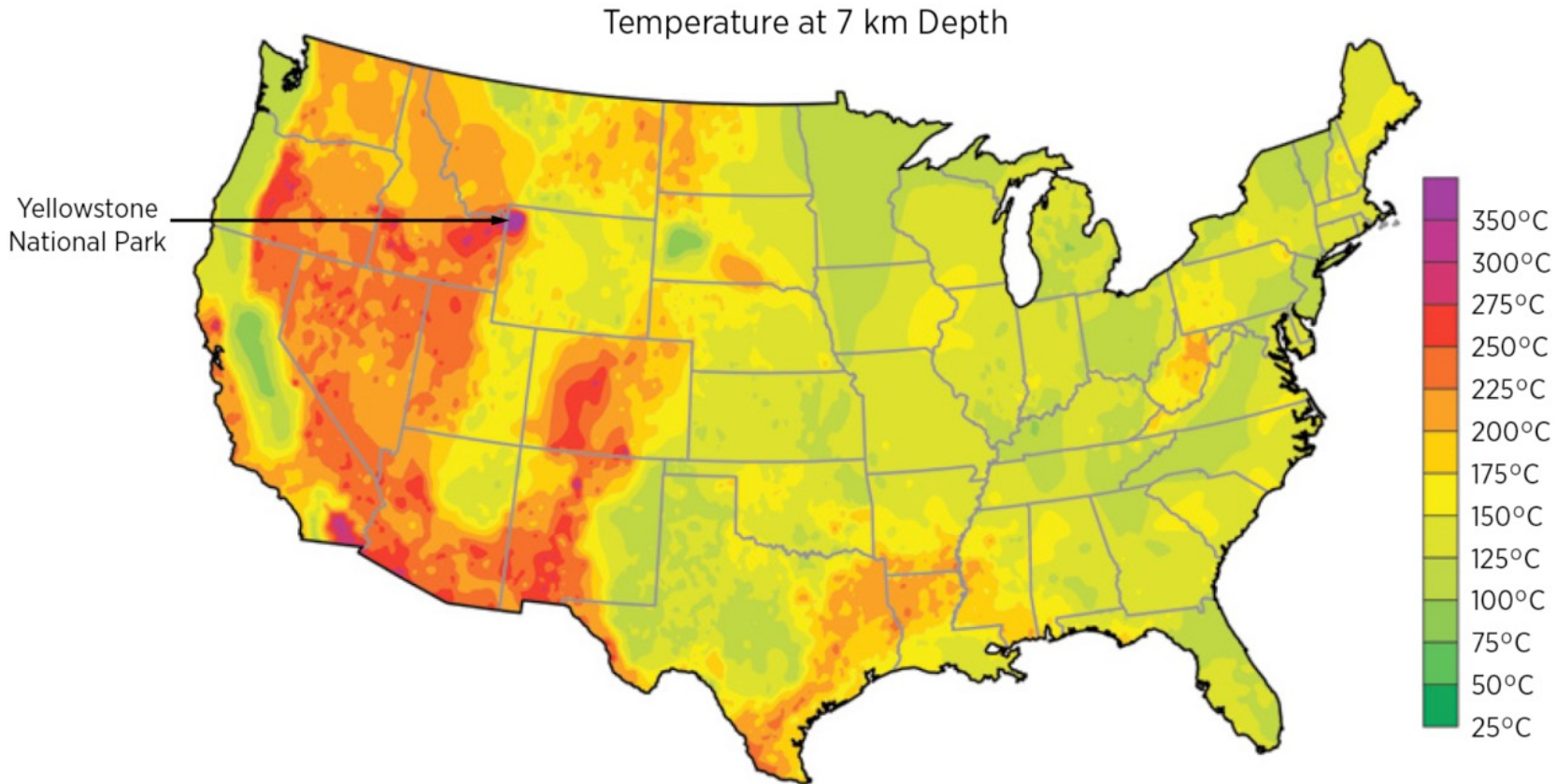
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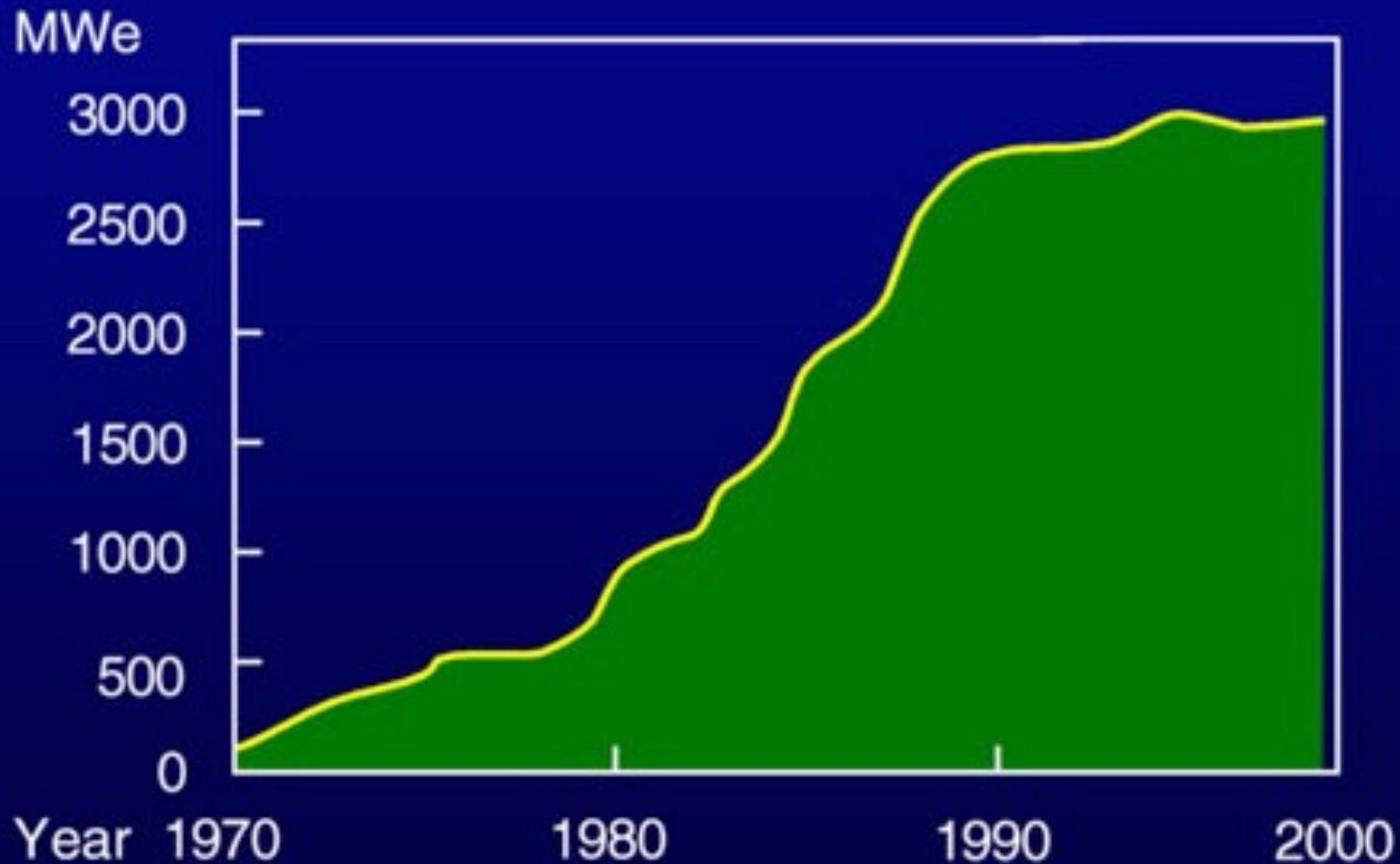
Geothermal electrical power output by country (2019)



Geothermal potential in U.S.



Growth in U.S. Geothermal Power



What is potential for geothermal energy development?

- Geothermal power could serve 100% of the electrical needs of 39 countries (over 620,000,000 people) in Africa, Central/ South America and the Pacific.

(Source: www.geotherm.org/PotentialReport.htm [link](#))

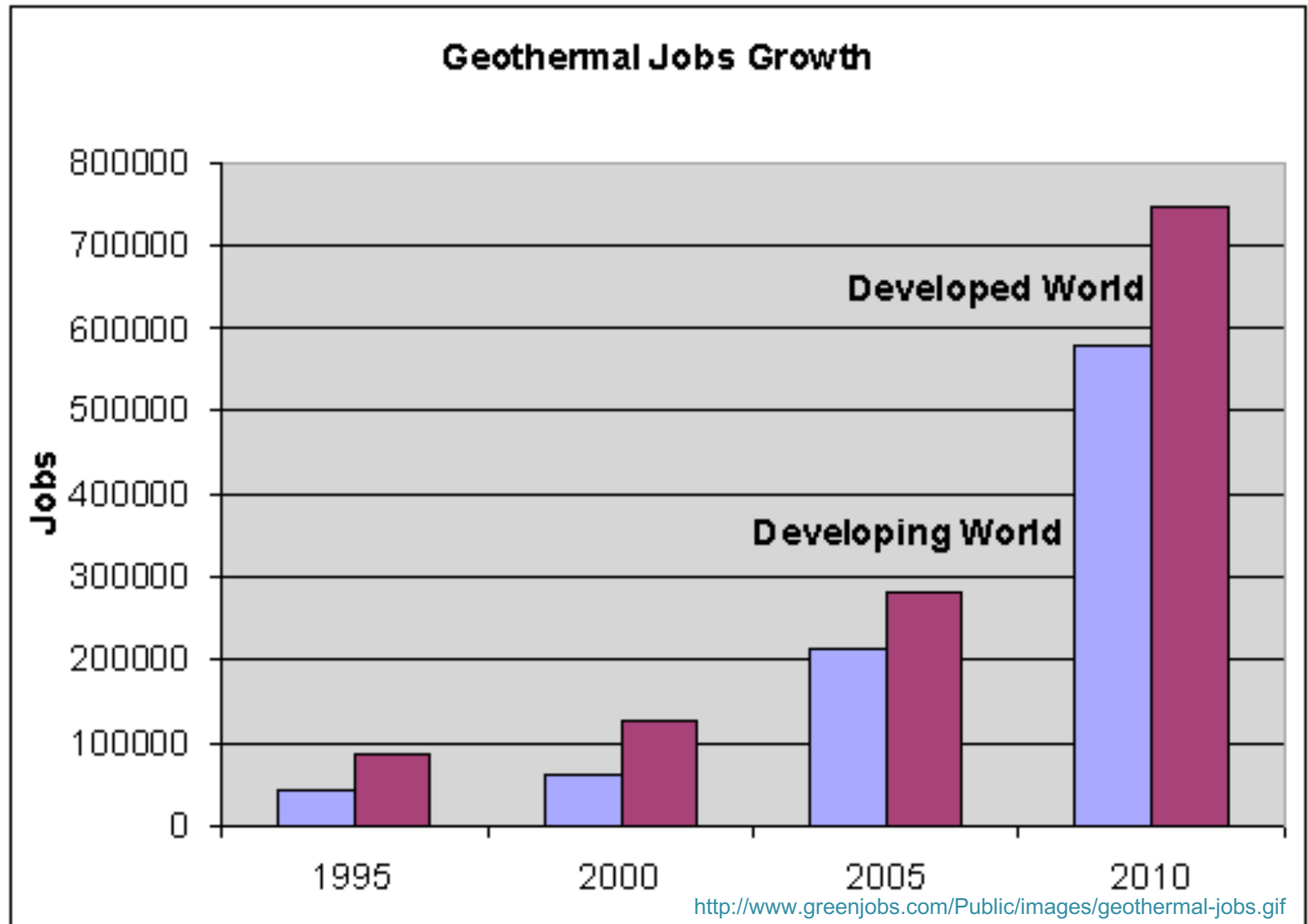
What is potential for geothermal energy development?

- Using current technology, geothermal energy from already-identified reservoirs can contribute 10% of U.S. energy supply.
- Inventory can grow with more exploration.
- Entire world resource base of geothermal energy calculated to be larger than those of coal, oil, gas and uranium combined.
- Further research and experience will improve geothermal resource base.

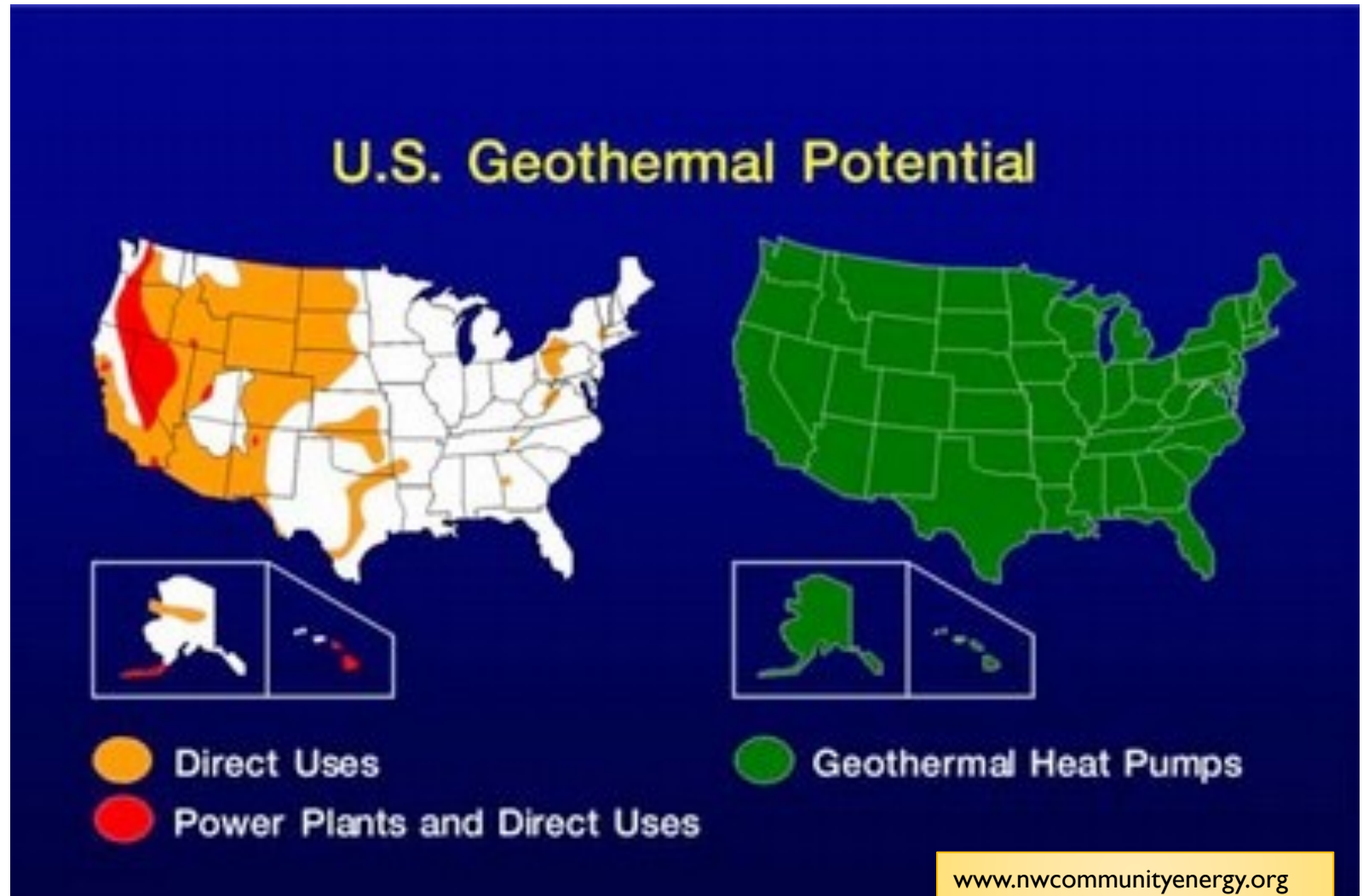
What is potential for geothermal energy development?

- According to Geothermal Energy Association (GEA), geothermal resources could supply over 30,000 MW of power by 2025
- Equivalent to 6 percent of today's total U.S. electricity needs, and equal to 100% of the electricity generated in California, Nevada and Idaho.

Employment in geothermal?



Location of geothermal potential in US

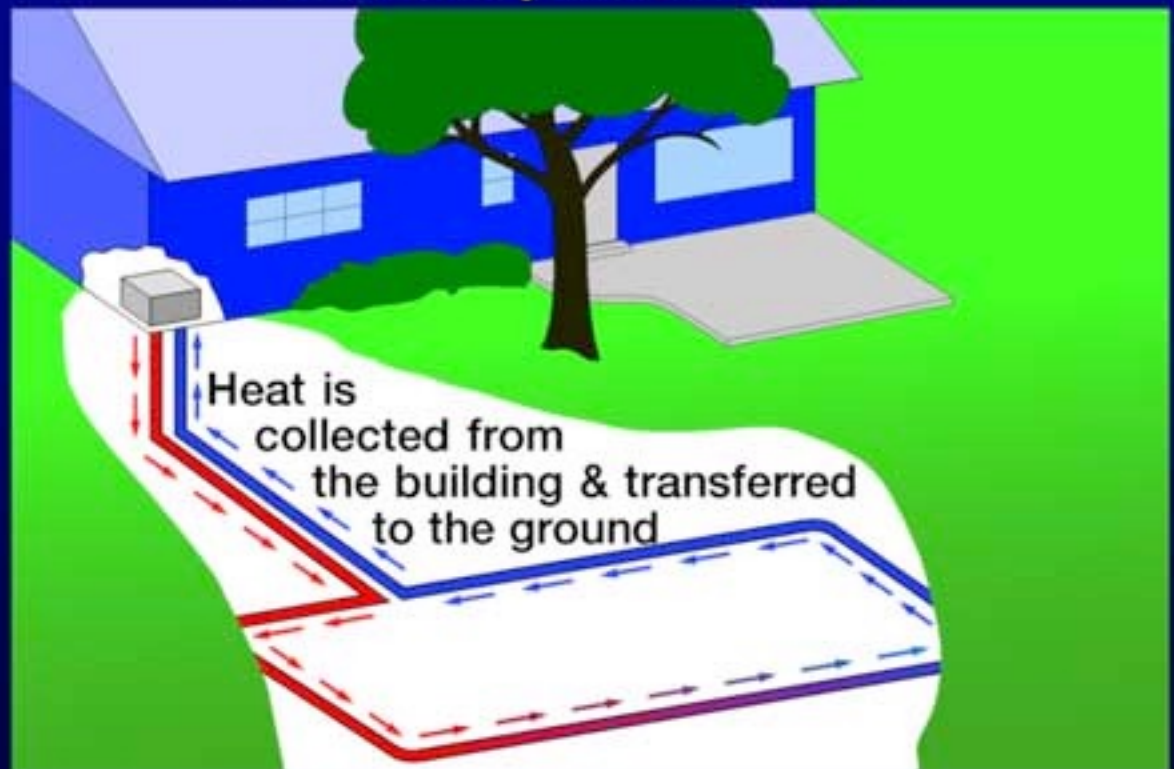


Geothermal heat pumps

Heat Pump in Winter



Heat Pump in Summer



Benefits of geothermal heat pumps

- Can be used almost anywhere worldwide
- Are energy and cost efficient
- Conserve fossil fuel resources
- Provide clean heating and cooling; no emissions from burning fuels

Deployment: 400,000 units in U.S.

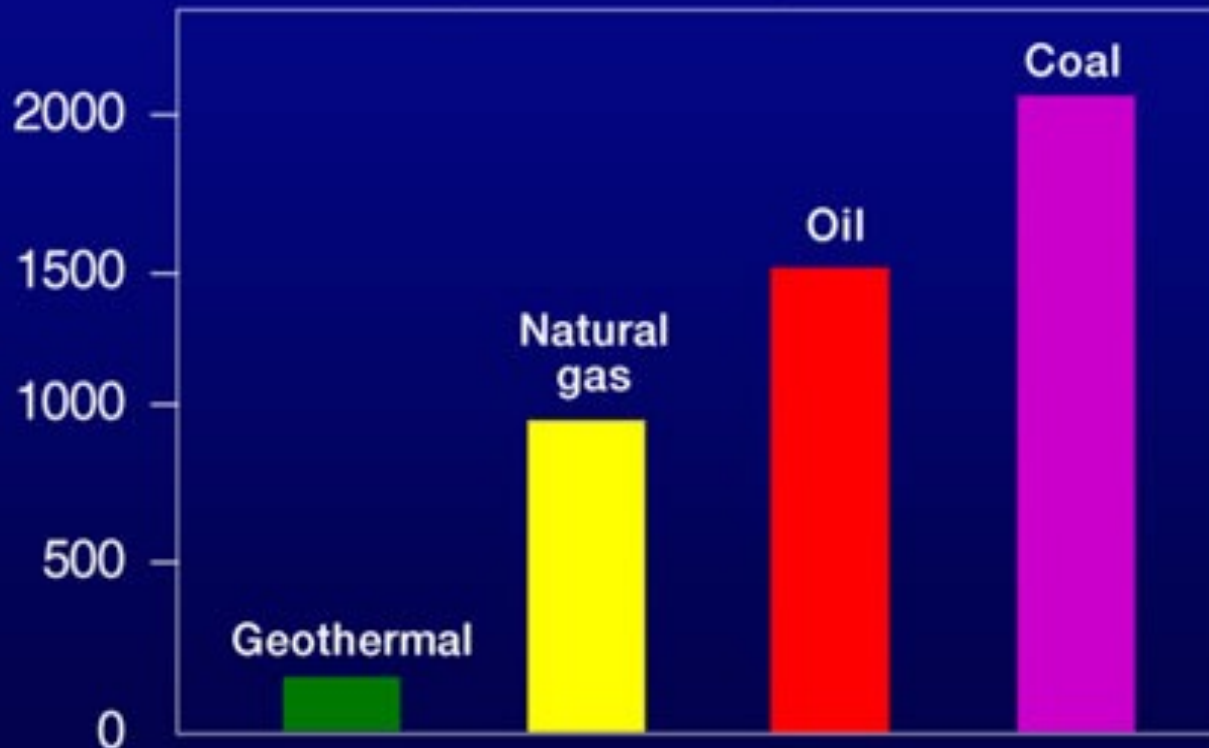
Yield: 1500 thermal mW of heating and cooling

Any environmental problems?

Impact	Probability of occurring	Severity of consequences
Air quality pollution	L	M
Surface water pollution	M	M
Underground pollution	L	M
Land subsidence	L	L-M
High noise levels	H	L-M
Well blow-outs	L	L-M
Conflicts with cultural and archaeological features	L-M	M-H
Social-economic problems	L	L
Chemical or thermal pollution	L	M-H
Solid waste disposal	M	M-H

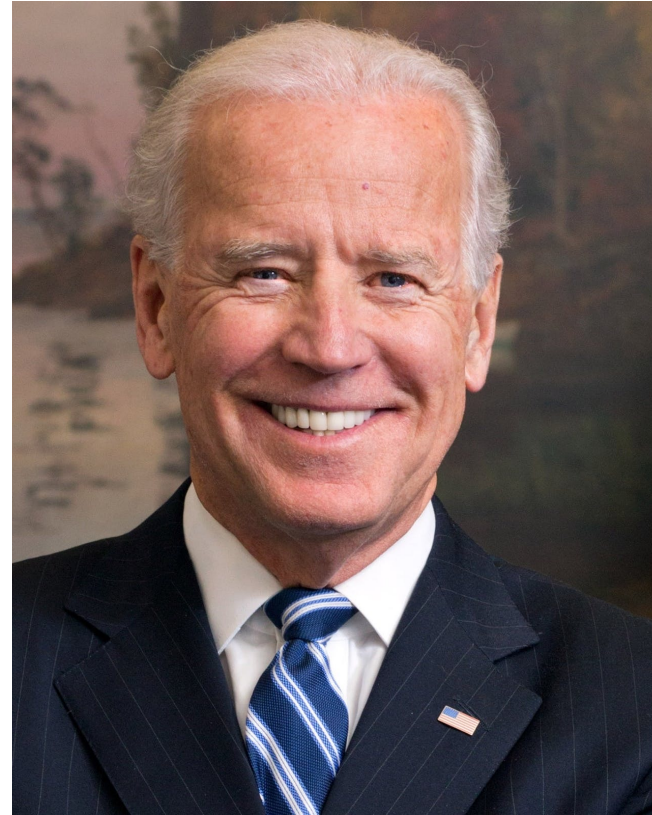
One clear environmental benefit

CO₂ Emissions Comparison (lbs/MW-hr)



Source EIA 1998; Bloomfield and Moore 1999

Trump vs Biden on Geothermal



Did their policies differ?
Was it an issue?