



C L E A N G R E E N R E N E W A B L E E N E R G Y



USGeothermal

Geothermal Primer

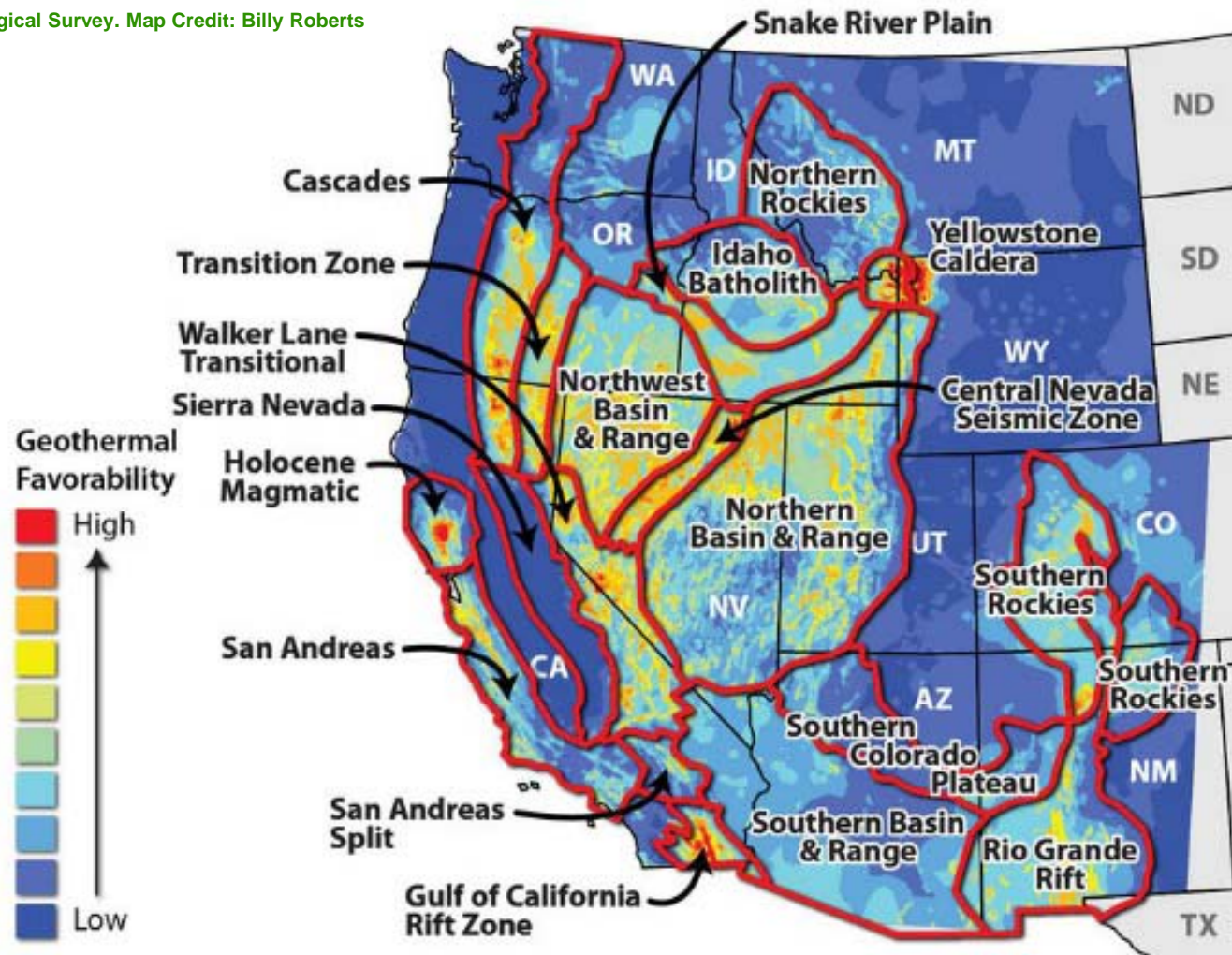


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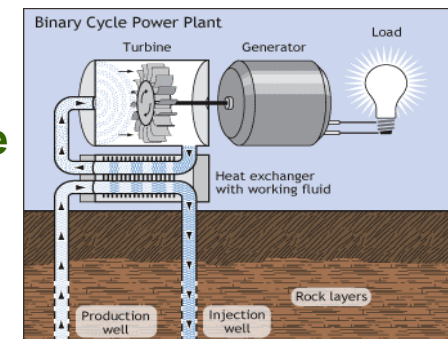
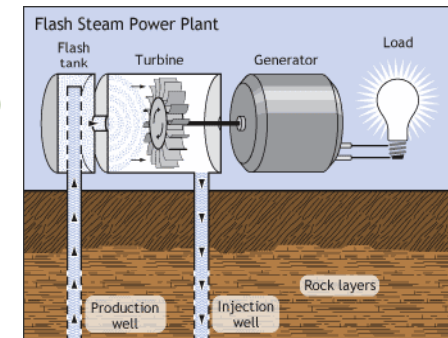
Geothermal Resources in the Western U.S.

Data source: United States Geological Survey. Map Credit: Billy Roberts

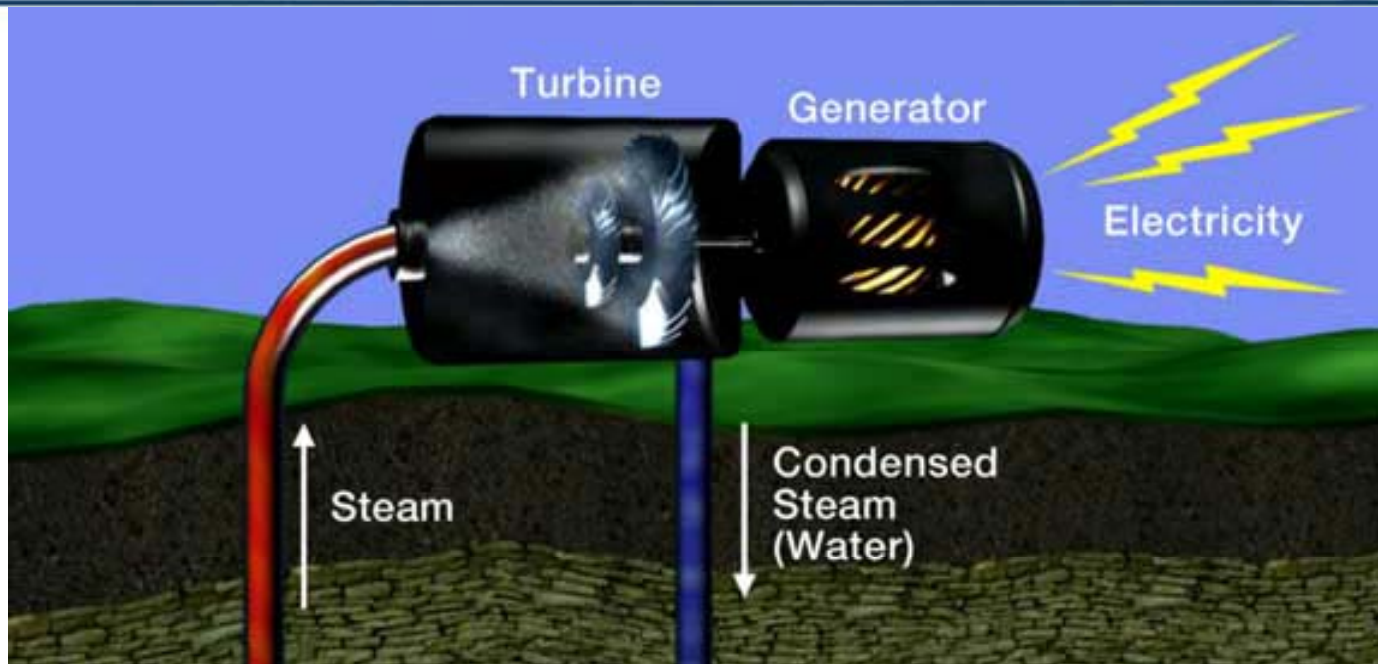


Geothermal Power Background

- **Produced by utilizing heat that naturally exists within the Earth's crust**
 - National Renewable Energy Lab (NREL) estimates that heat within 10,000 meters of earth's surface is 50,000 times greater than energy that is available from petroleum and natural gas
- **Geological anomalies create "shallow" reservoirs of geothermal fluids (steam and water) that can be economically exploited**
 - Typically reservoirs are 1,000 – 12,000 feet deep
- **Geothermal fluids act as heat carriers. Those fluids are piped to the surface and used to drive turbine generators**
- **Geothermal fluid is reinjected to sustain reservoir pressure**
- **Geothermal power is renewable without significant output deterioration over time**

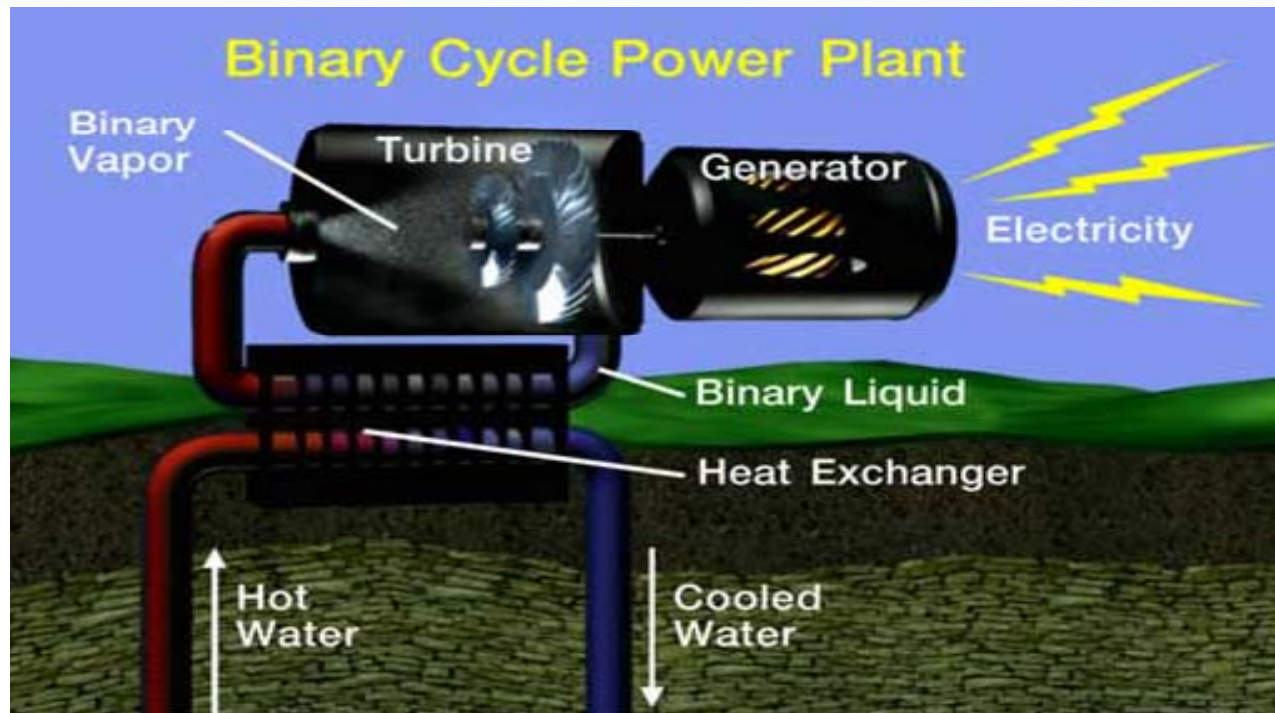


Steam Power Plant



- In dry steam or flash power plants, the hot steam (or flashed hot water) passes directly into a steam turbine.
- The steam spins the turbine blades, which in turn spin the generator making the electricity.
- Condensed steam is returned into the reservoir to be reheated.

Binary Cycle Power Generation



- In a binary cycle plant, hot water from the ground is run through a heat exchanger to vaporize a working fluid (hydrocarbon or refrigerant) that powers the turbine generator.
- The geothermal water is returned into the reservoir to be reheated.

Geothermal Overview

- **Large existing installed base in the United States**

- 3,386 MW⁽²⁾ in production as of year end 2012
- Comparative production of geothermal, wind, and solar in the United States in 2012⁽¹⁾ : (thousand MWh)
 - Wind 140,089
 - Geothermal 16,791
 - Solar 4,342(Wind surpassed geothermal in 2005)

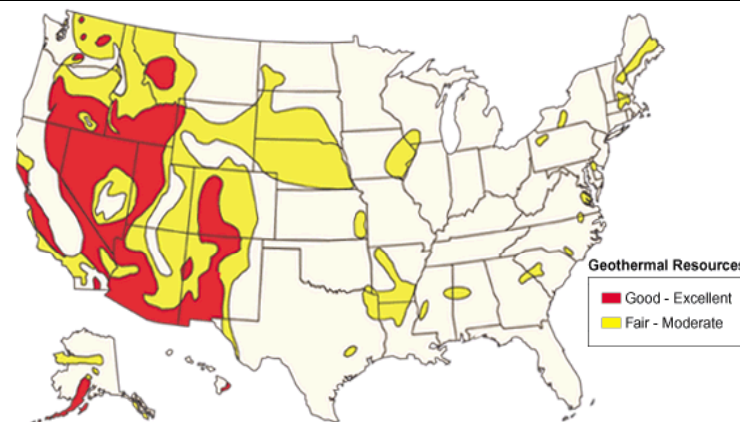
- **Globally, there is 11,224 MW⁽¹⁾ in production**

- United States is the largest producer in the world
- The first geothermal power plants in the U.S. were built in 1962 at The Geysers dry steam field in Northern California
 - The Geysers are the largest producing geothermal field in the world

- **Geothermal power has incredible potential as an energy source**

(1) GEA Data for 2012
(2) Source: EIA Data for 2012

US Electric Geothermal Resource Survey



Source: US DOE

NREL Estimated US Geothermal Potential

Shallow – Identified.....30,000 MW
Shallow – Unidentified.....120,000 MW
Co-production & Geo-pressure.....>100,000 MW
Enhanced Geothermal Systems.. 13,000,000 MW

Source: NREL

Geothermal Electricity Production in U.S. by State

■ California	2,732 Megawatts	
■ Nevada	517 Megawatts	
■ Utah	48 Megawatts	
■ Hawaii	38 Megawatts	(25% of Big Island's total energy)
■ Oregon	33 Megawatts	
■ Idaho	16 Megawatts	
■ Alaska	0.7 Megawatt	
■ Wyoming	0.3 Megawatt	

Dry Steam:	1,585 MW
Flash:	997 MW
Binary:	<u>804 MW</u>
Total	3,386 MW

Source: Geothermal Energy Association – 2013 Annual Generation Report

Total Projects in Development by State

State	Total Projects	Planned Capacity Additions (MW)		Estimated Resource (MW)	
		Low	High	Low	High
AK	6	50	50	95	95
AZ	2	2	2	102	102
CA	33	995	1,061	1,736	1,827
CO	3	20	40	60	60
HI	3	-	-	-	-
ID	11	83	83	439	514
ND	2	0.60	0.82	-	-
NM	1	15	15	-	-
NV	75	1,056	1,061	2,150	2,275
OR	18	73	77	208	270
TX	1	1	1	-	-
UT	19	215	215	260	280
WA	1	-	-	100	100
TOTAL	175	2,511	2,606	5,150	5,523

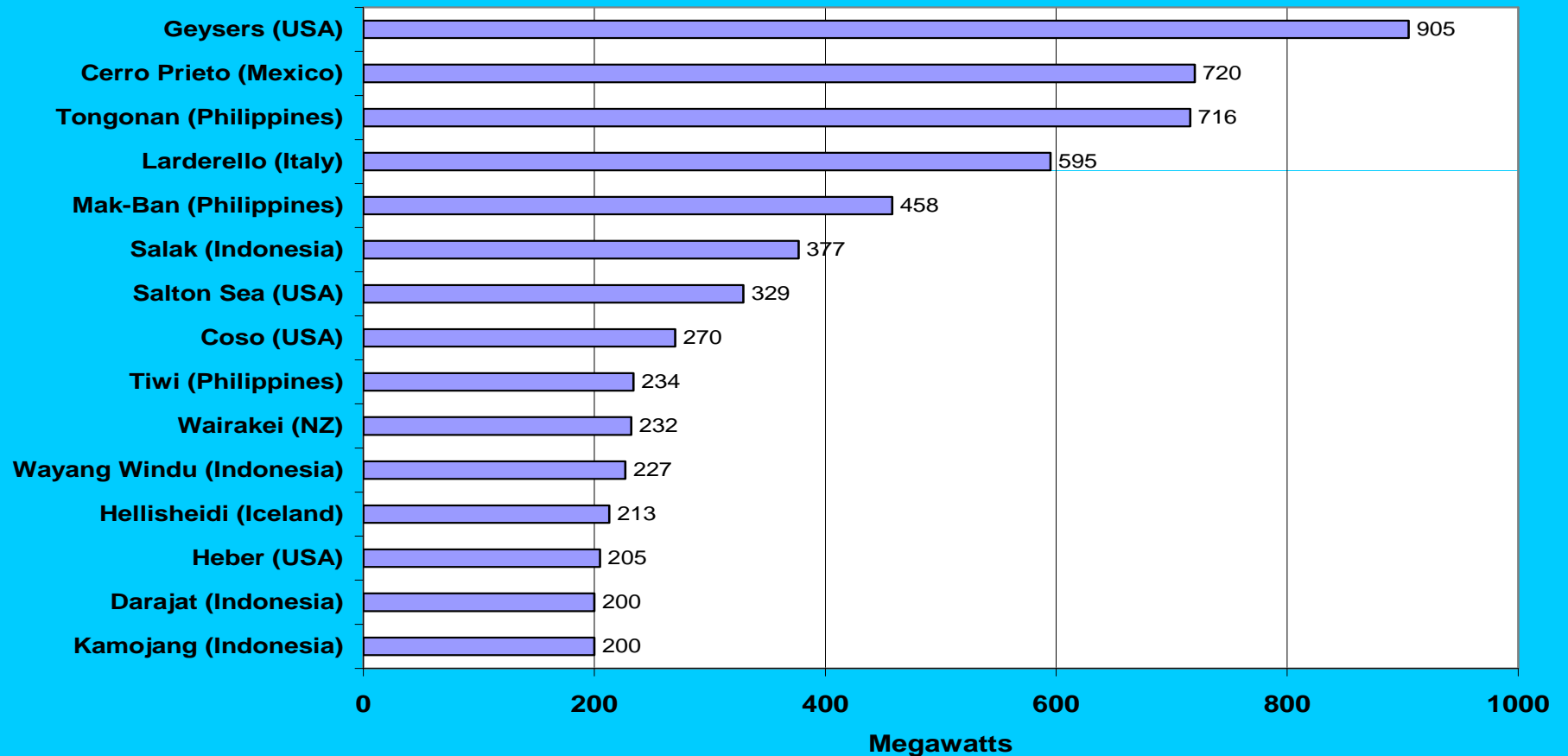
Source: Geothermal Energy Association – 2013 Annual Generation Report

World's Largest Geothermal Fields

(MW capacity)

World's Largest Geothermal Fields

Reference: Proceedings World Geothermal Congress April 2010



Why Geothermal?

Versus Traditional Power Generation

- Clean and renewable generating source
- Cost competitive with traditional sources in many geographic areas
 - No commodity risk and/or price volatility from fuel inputs
- No emissions = easier permitting process in power hungry Western US
- High availability versus all technologies
- Incentives enhance attractive project returns



Wyoming Coal Plant

Versus Other Renewable Power Generation

- Base load power
 - Not dependent on variables such as the time of day, cloud cover, etc.
 - 95% utilization versus 30-35% for wind and solar
 - Can constitute larger portion of a utility's generating portfolio
- Results in lower production costs per megawatt produced
- More attractive project returns
- Smaller footprint and reduced visual impact versus wind and solar
- However longer development lead times and higher exploration risk/cost



Natural Geyser

Specific Barriers to Geothermal Development

Drilling, Drilling, Drilling.....

- High risk - resource discovery (3 to 5 years)
- Cost per well \$2 to \$8 million
- Lack of drilling and development price incentives
- Need to reward investors with higher returns
- Need to create new era of geothermal drilling based on feed-in tariff

Other Factors.....

- Long development lead times for plant equipment
- Capital-intensive
- Regulatory patchwork

This is what it is all about!



CLEAN GREEN RENEWABLE ENERGY

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Direct Use Applications

- Direct use applications displace about 1.6 Million barrels of oil annually in the U.S.

- District Heating
- Process heat
- Agriculture
- Aquaculture
- Balneology
(Hot spring and water bathing)



District Heating Applications



Geothermal Drilling at
Capitol Building,
Boise, Idaho

