DOE OFFICE OF INDIAN ENERGY

Foundational Courses
Renewable Energy Technologies
GEOTHERMAL

Presented by the National Renewable Energy Laboratory



U.S. DEPARTMENT OF ENERGY | Office of Indian Energy

Course Outline

What we will cover…

- About the DOE Office of Indian Energy Education Initiative
- Course Introduction
- Resource Map & Project Scales
- Technology Overview(s):
  - Siting
  - Costs
- Successful Project Example(s)
- Policies Relevant to Project Development
- Additional Information & Resources

Introduction

The U.S. Department of Energy (DOE) Office of Indian Energy Policy & Programs is responsible for assisting Tribes with energy planning and development, infrastructure, energy costs, and electrification of Indian lands and homes.

As part of this commitment and on behalf of DOE, the Office of Indian Energy is leading *education* and *capacity building* efforts in Indian Country.

Training Program Objective & Approach

Foundational courses were created to give tribal leaders and professionals background information in renewable energy development that:

- *Present foundational information on strategic energy planning, grid basics, and renewable energy technologies;*
- *Break down the components of the project development process on the commercial and community scale; and*
- *Explain how the various financing structures can be practical for projects on tribal lands.*

NREL's Presenter on Geothermal Energy is

Kermit Witherbee

Kermit.Witherbee@nrel.gov

Kermit Witherbee is with the National Renewable Energy Laboratory (NREL) working as a Geothermal Energy Geologist and Analyst in the Geothermal Technologies Program. He is involved in a variety of projects, including: geothermal resource assessment, geothermal regulatory road mapping, policy analysis, and development of Web-based geothermal data and analysis applications. Prior to joining NREL, he served as the Bureau of Land Management's National Geothermal Program Manager where he was engaged in national level policy development, strategic planning, and budget. He has a Bachelor's and Master's degree in Geology from the State University of New York at Oneonta and is a registered Professional Geologist.

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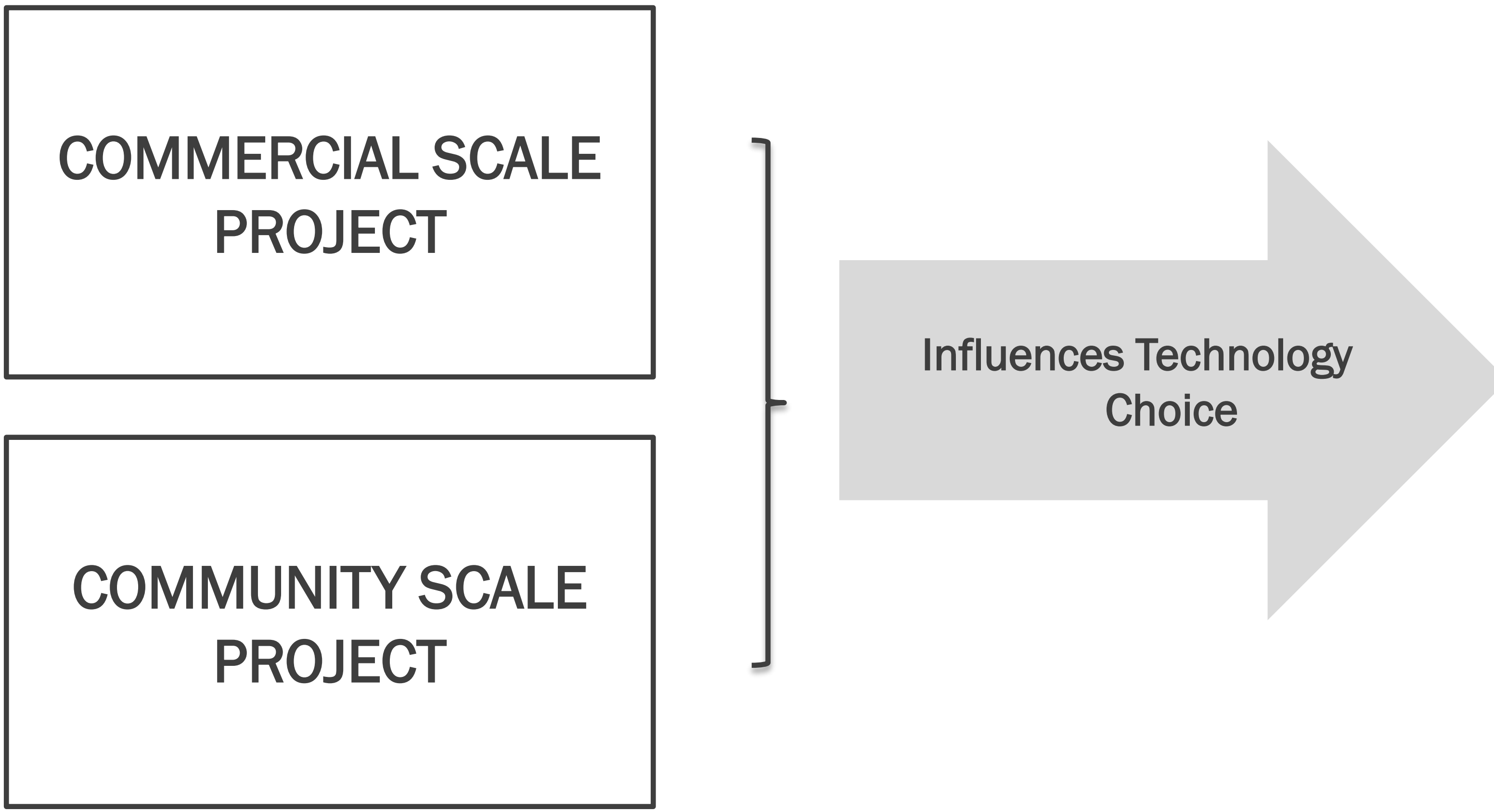
Key Knowledge Takeaways

- Geothermal Geology and Resources
- Geothermal Technology
- Environmental Impacts
- Successful Examples
- Geothermal Policies, Leasing, and Development

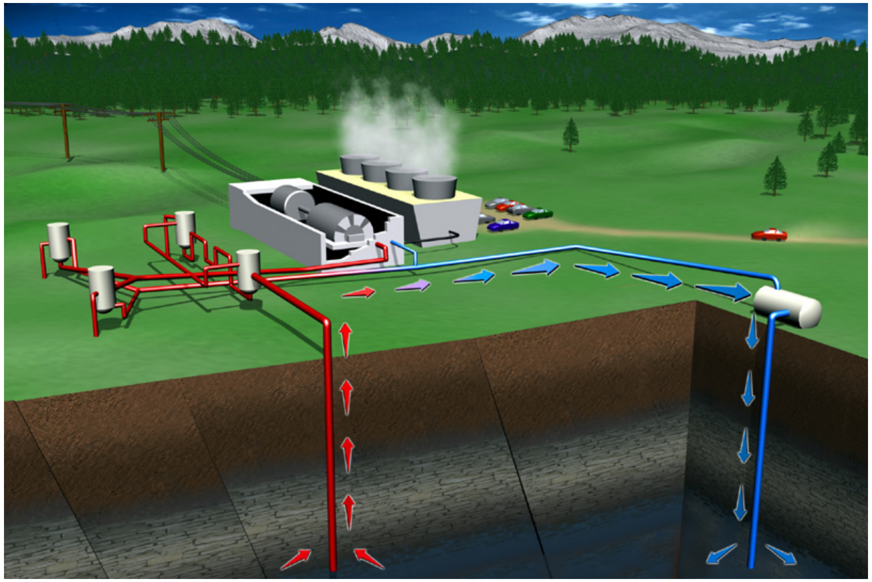
Greenhouse Heated by Geothermal, NREL/PIX 13981

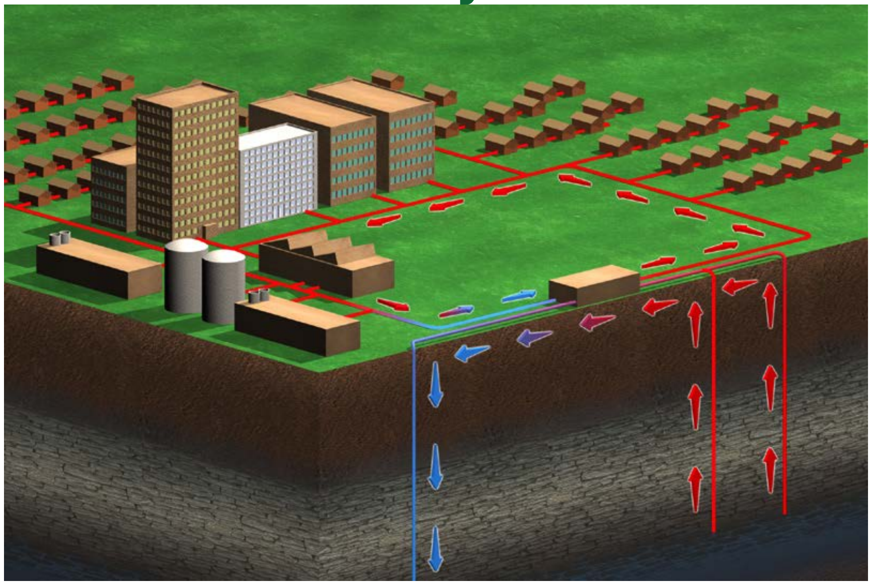
Geothermal Binary Power Plant in Empire, Nevada, NREL/PIX 13093

Commercial or Community Scale?



Commercial or Community Scale?





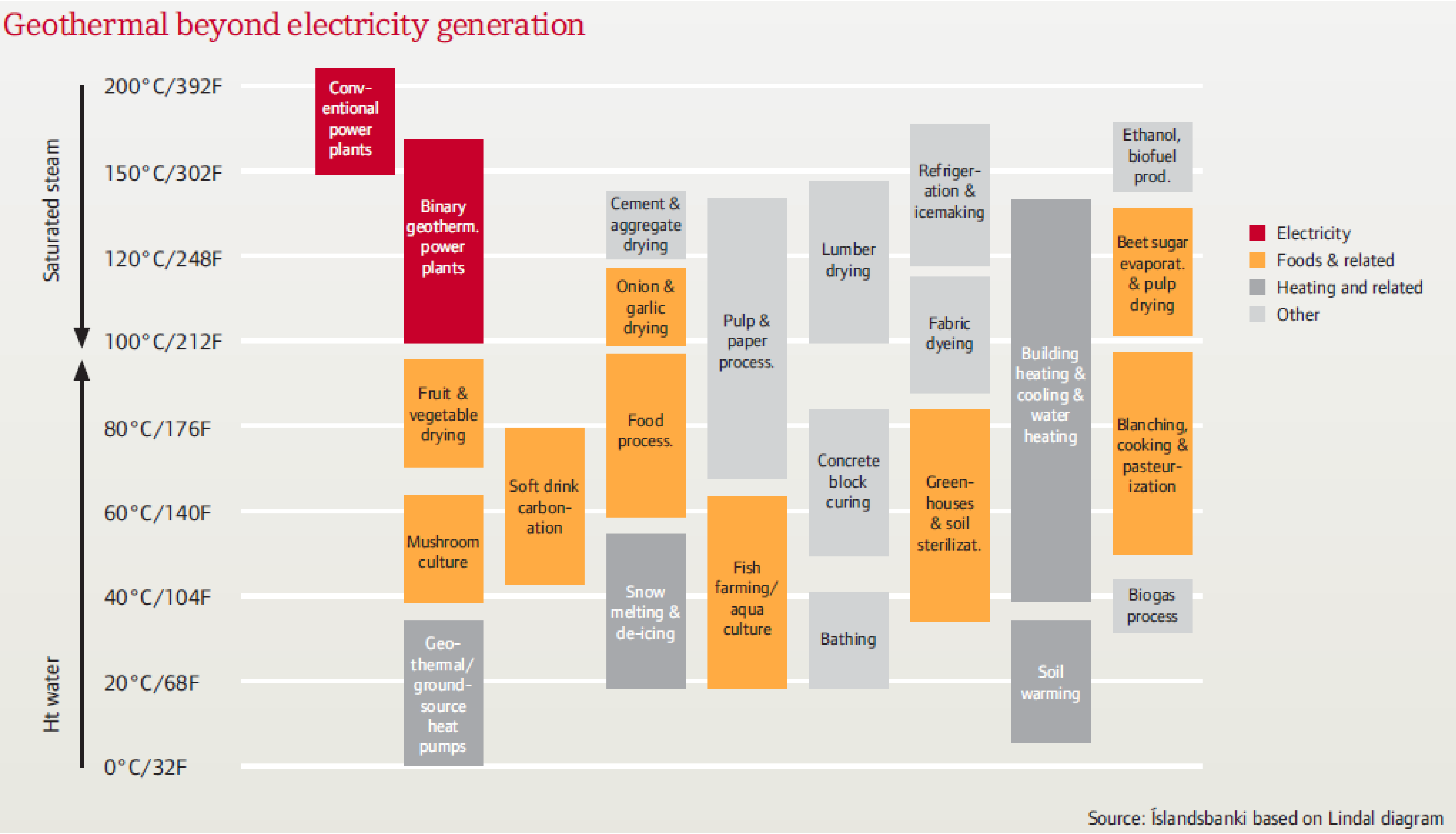
Electricity Generation

- Distributed Power
- Central Station Power

Direct Use

- District Heating
- Process Heat
- Agriculture
- Aquaculture

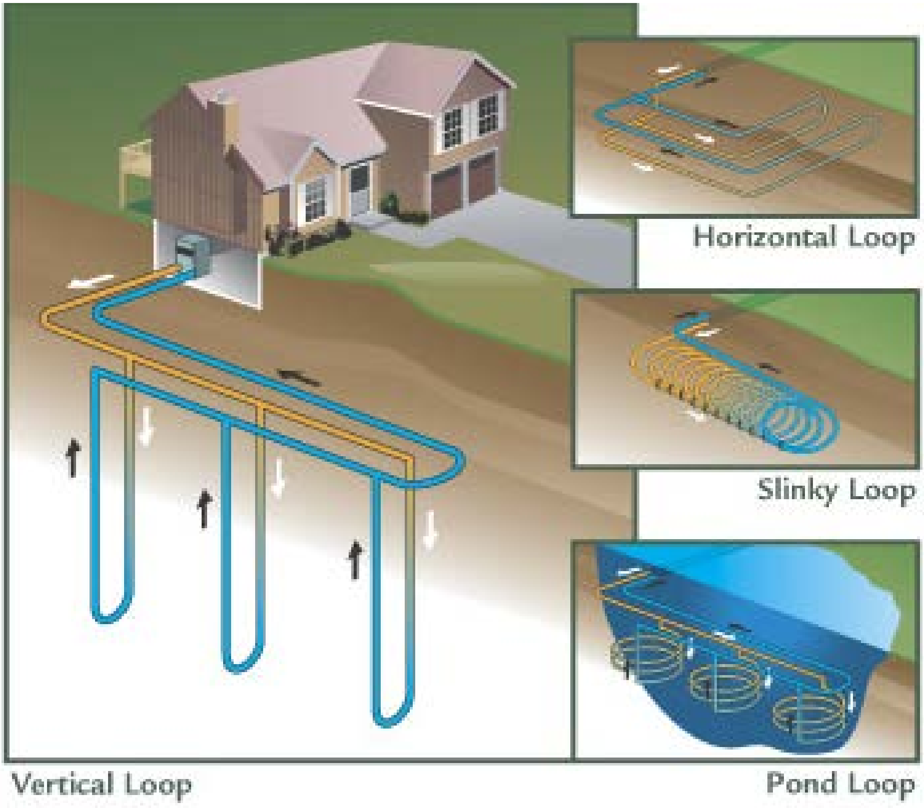
Geothermal Applications



Source: Islandsbanki, 2011, U.S. Geothermal Industry Overview Islandsbanki Geothermal Research

Residential Scale Geothermal Heat Pumps

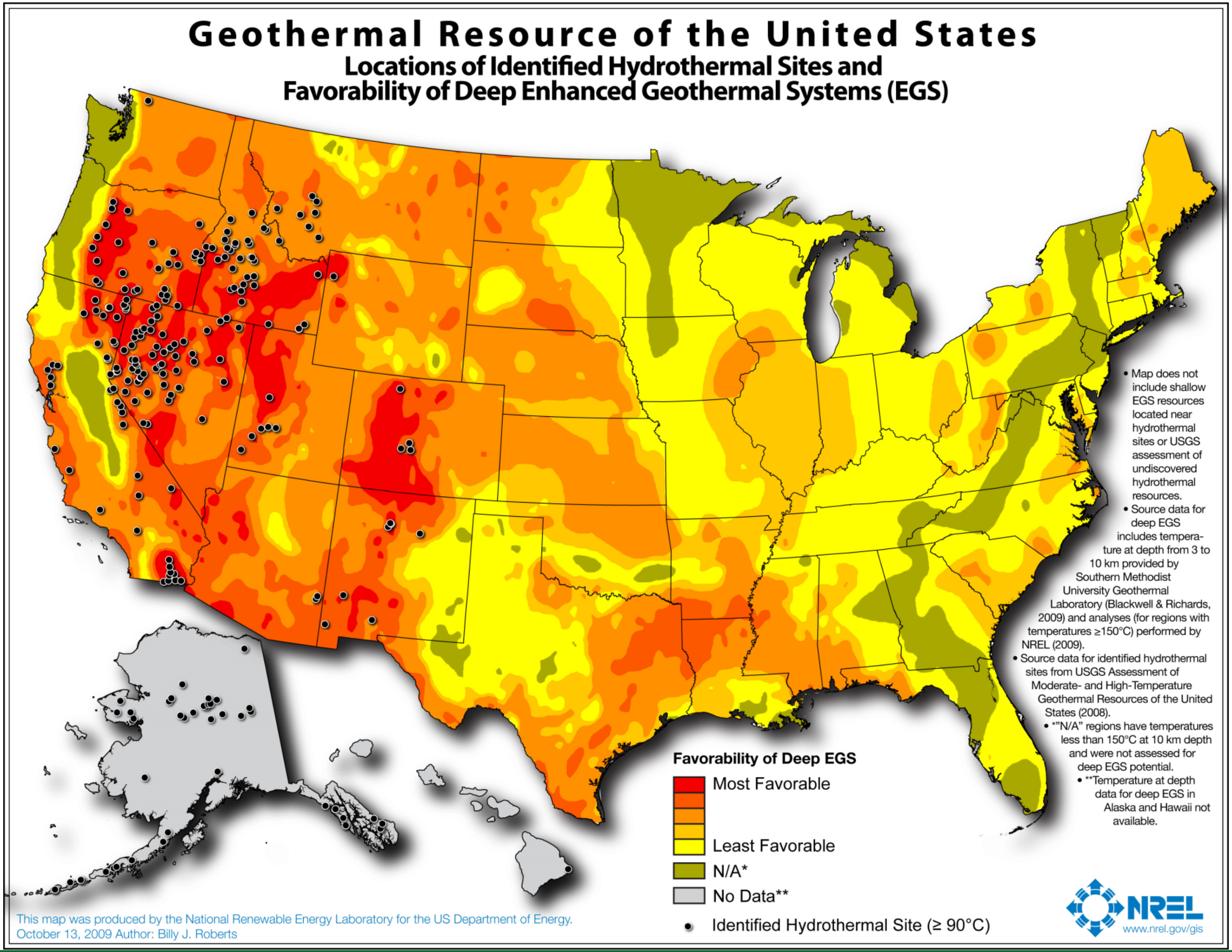
- Highly efficient method of providing heating and cooling
- Uses ground temperature as a renewable resource for pumping heat in winter and rejecting heat in summer
- Cost effective
- Economic and environmental benefits



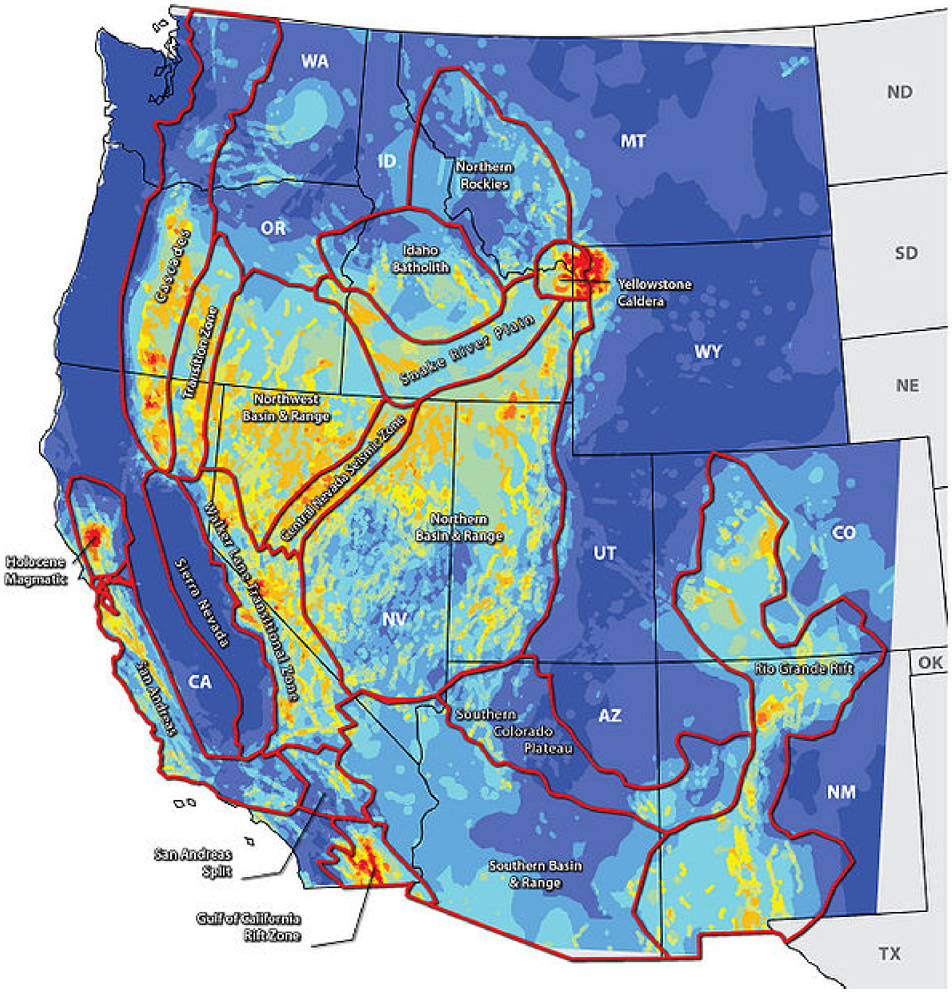
Resources & Maps

- NREL Geographic Information System (GIS) Maps: http://www.nrel.gov/gis/maps.html
- NREL Geothermal: http://www.nrel.gov/gis/geothermal.html
- DOE Geothermal Technologies Program: http://www1.eere.energy.gov/geothermal/faqs.html
- Western Area Power Administration: http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf

Geothermal Resource



Geothermal Resources



Geothermal Exploration Districts and Favorability

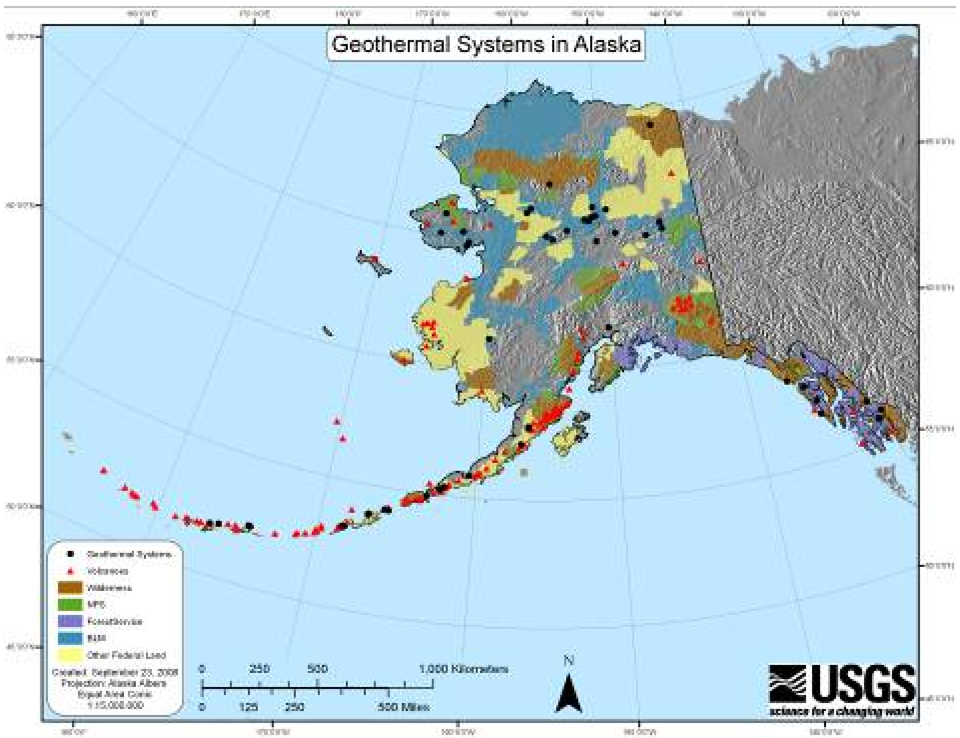
Geothermal favorability is a surface showing relative favorability for the presence of geothermal systems in the western United States. It is an average of 12 models that correlates different geological and geophysical factors to the known presence of moderate (90 - 150° C) to high (> 150° C) temperature geothermal systems. Exploration regions were derived from physiographic regions of the conterminous United States. Data sources: United States Geological Survey.

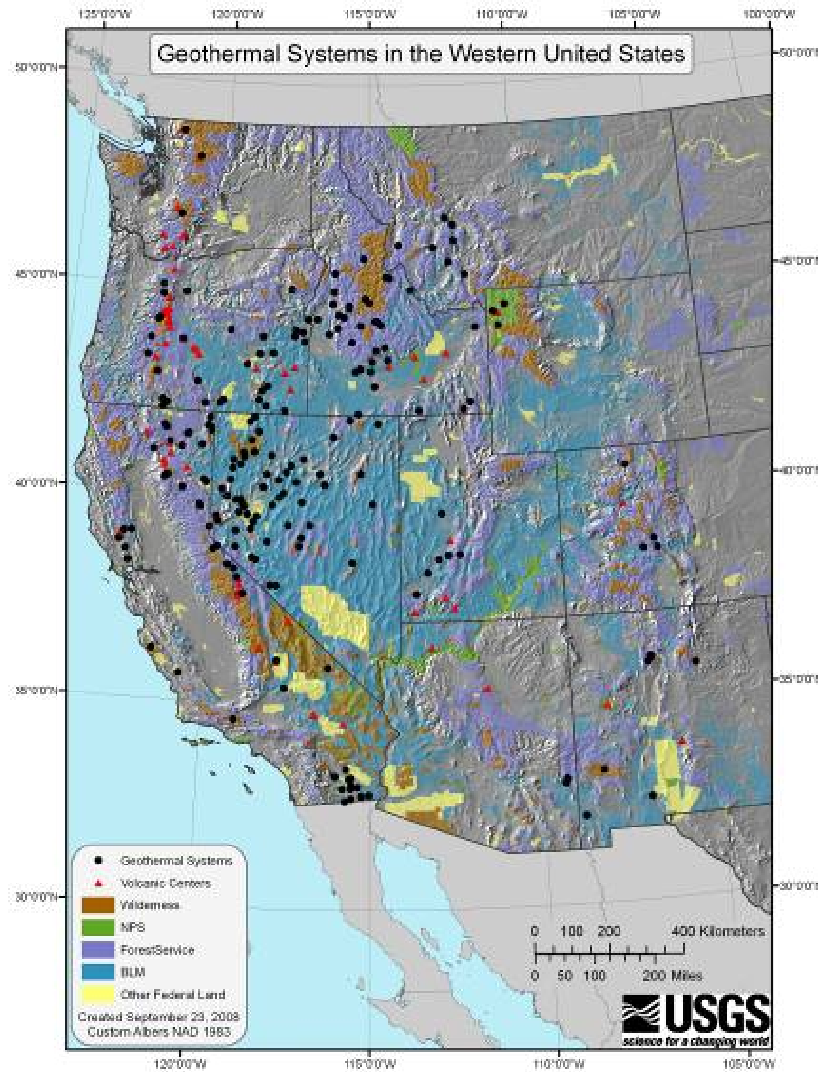
Geothermal Favorability

High

Low

Geothermal Systems and Federal Lands





Geothermal Resources

State	Existing Systems	Identified Mean Megawatt Electrical (MWe)	Undiscovered Mean (MWe)	Engineered Geo Systems Mean (MWe)
Alaska	53	677	1,788	NA
Arizona	2	26	1,043	54,700
California	45	5,404	11,340	48,100
Colorado	4	30	1,105	52,600
Hawaii	1	181	2,435	NA
Idaho	36	333	1,872	67,900
Montana	7	59	771	16,900
Nevada	56	1,391	4,364	102,800
New Mexico	7	170	1,498	55,700
Oregon	29	540	1,893	62,400
Utah	6	184	1,464	47,200
Washington	1	23	300	6,500
Wyoming	1	39	174	3,000
Total	248	9,057	30,033	517,800

Source: U.S. Geological Survey (USGS) Fact Sheet 2008-3062

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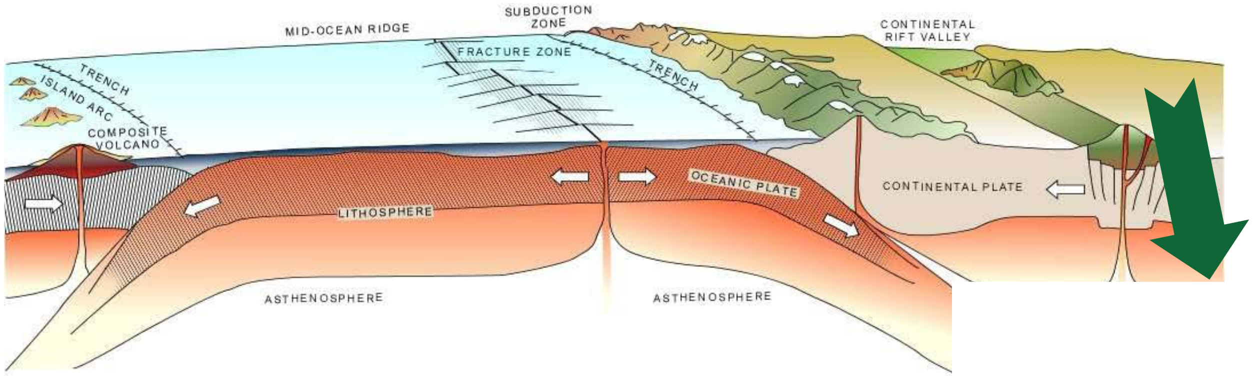
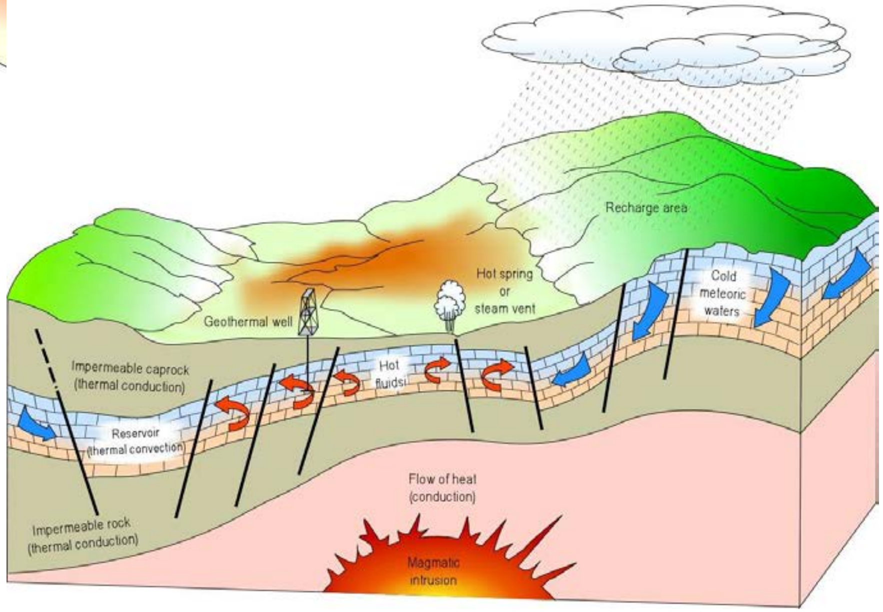
Plate Tectonic Processes Schematic Cross-Section

"Magmatic" Systems
Cascade Range



"Extensional" Systems – "Rifting"
Basin and Range
Rio Grand Rift
Imperial Valley
East Africa Rift Valley



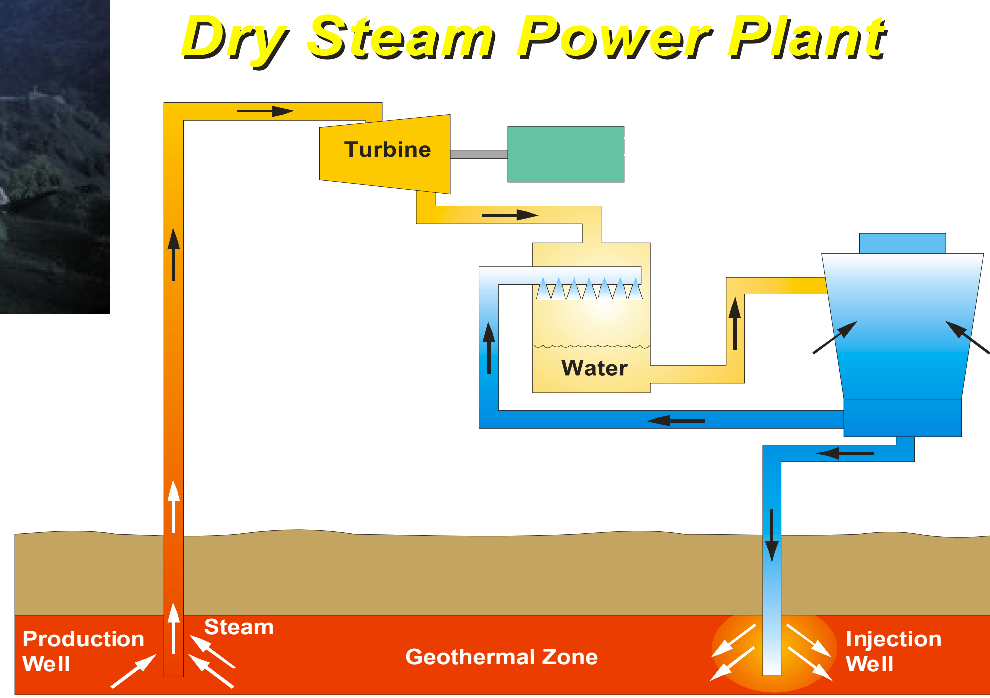
Geothermal Environments

- Hydrothermal Systems
  - High Temperature (>150°C, > 302°F)
    - Liquid- and Vapor-Dominated
  - Moderate Temperature (90° to 150°C, 194° to 302°F)
    - Liquid-Dominated
  - Low Temperature (<90°C, <194°F)
    - Liquid-Dominated
- Hot Dry Rock
  - Enhanced (Engineered) Geothermal System
- Cogeneration
  - Oil and Gas
  - Geopressure

Dry Steam Power Plant (>455 ° F)

First Geothermal Power Plant, 1904, Larderello, Italy

Dry steam plants use steam as the primary geothermal fluid. The steam is produced from the reservoir, which directly turns the turbine, that drives the generator to produce electricity. This geothermal technology is the oldest and dates to 1904, with the first documented generation of electricity in Lardello, Italy.



The Geysers Geothermal Area

World's largest dry-steam geothermal field, 22 power plants, total capacity of 750 MWe

Well Depth: 650-3350 meters (M) (2130-8200 feet [ft])
Temperature: 240º- 250ºC (460º-480ºF)

Flash Power Plant (300°-700°F)

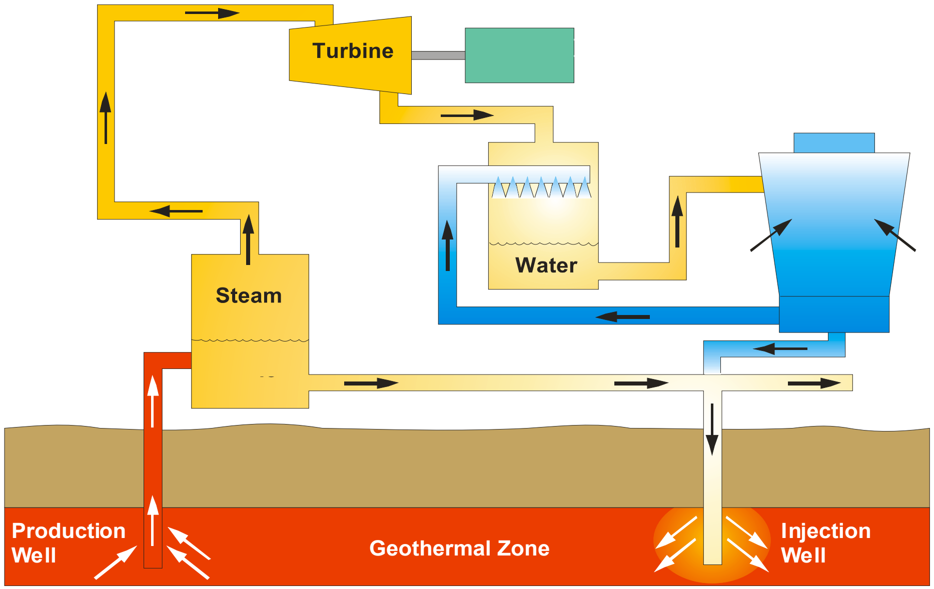
Net Capacity: 23 Megawatt

NREL/PIX 13984

- Blundell Power Plant flash plant with binary bottom cycling unit
- Well Depth: 260-2,230 M (850-7300 ft)
- Temperature: 138°-267°C (280°-512°F)

Geothermally heated water under pressure is separated in a surface vessel (called a steam separator) into steam and hot water. The steam is delivered to the turbine, and the turbine powers a generator. The liquid is injected back into the reservoir. A dual flash cycle separates the steam at two different pressures and produces 20%-30% more power than a single flash cycle at the same fluid flow.

Flash Steam Power Plant



Binary Power Plant (250°-360°F)

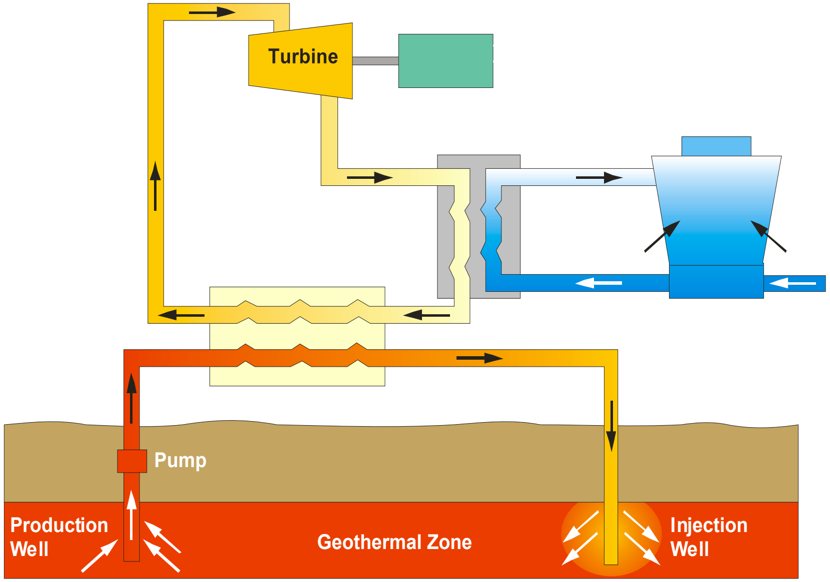
NREL/PIX 10991

Mammoth-Pacific Power Plants: two hydrothermal binary power plants generate enough power for approximately 40 MWe

Well depth: 150-750 M (490-2460 ft)
Temperature: 150º-175ºC (300º-350ºF)

Binary geothermal power plants use two closed loop systems:

1. The geothermal fluid is pumped from the reservoir circulated through a heat exchanger and re-injected into the reservoir.
2. A working fluid or refrigerant (i.e., isobutene or other organic fluid) is heated in the heat exchanger, which transfers the heat energy from the geothermal water to the working fluid. The secondary fluid expands into gaseous vapor. The force of the expanding vapor, like steam, turns the turbines that power the generators.



Example Using Low-Temperature Geothermal

Chena Hot Springs Resort in Alaska

- Commissioned in 2006
- Off grid sustainable geothermal power and heat for multiple applications
- Commercial Power Production: Lowest in the world at 165^{o} F

Photos courtesy of Chena Hot Spring Resort

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

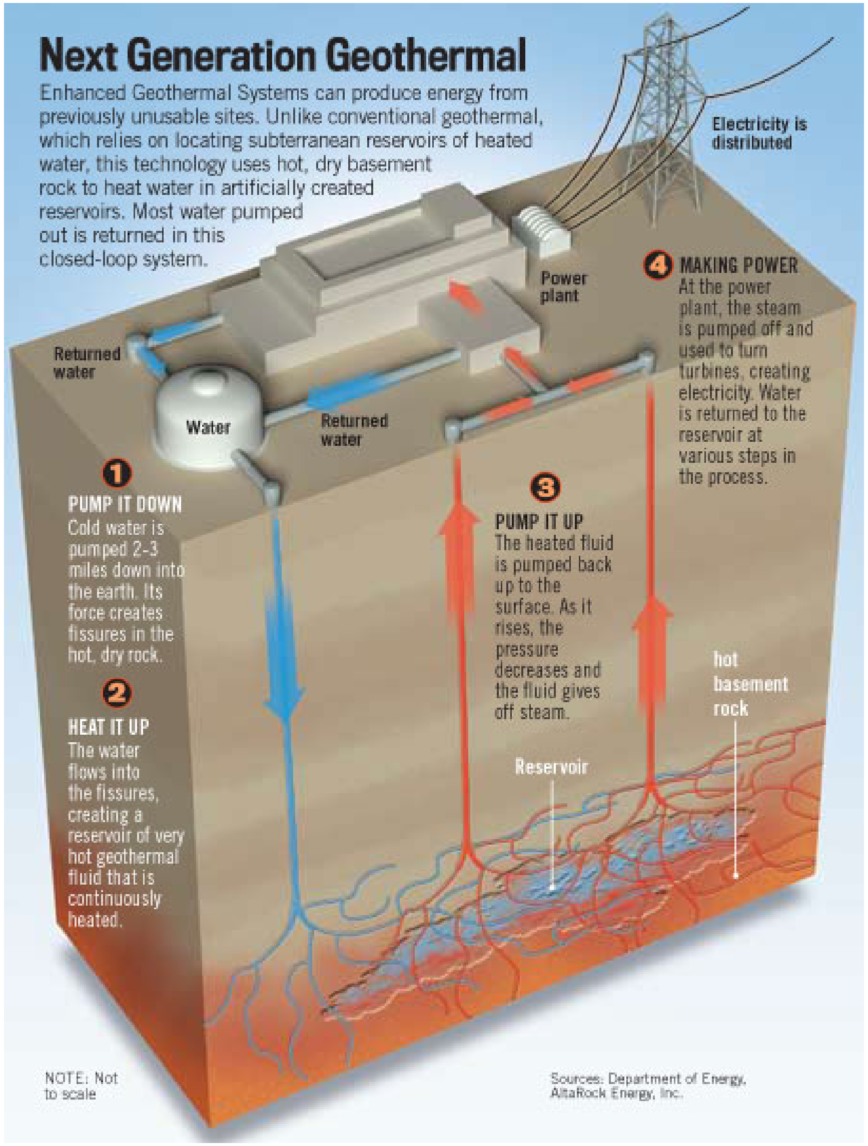
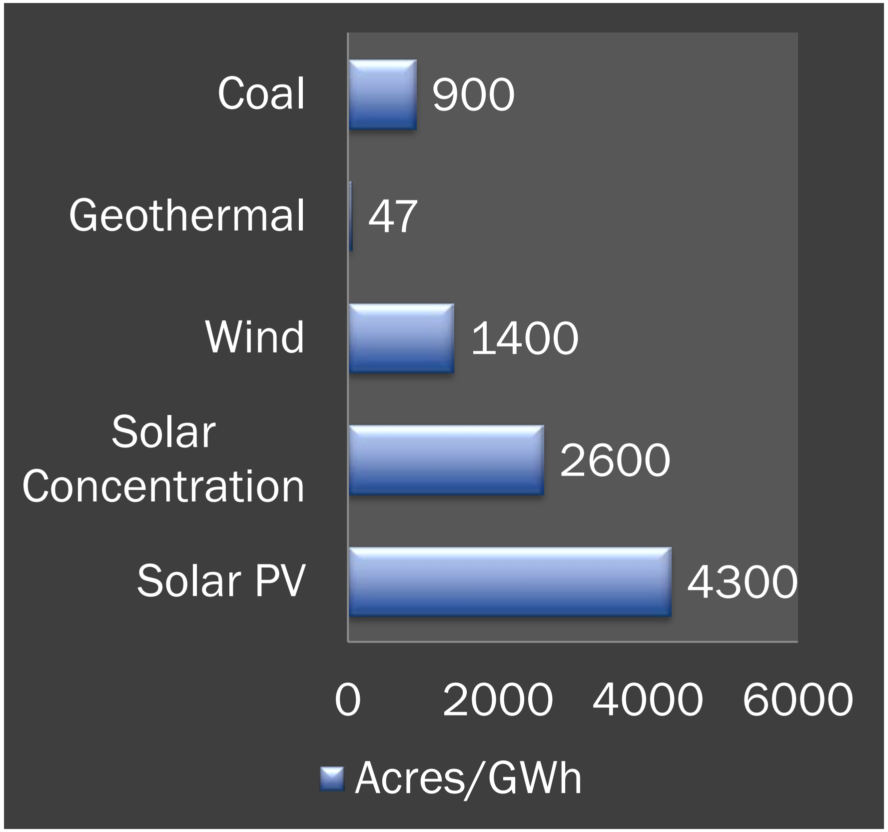


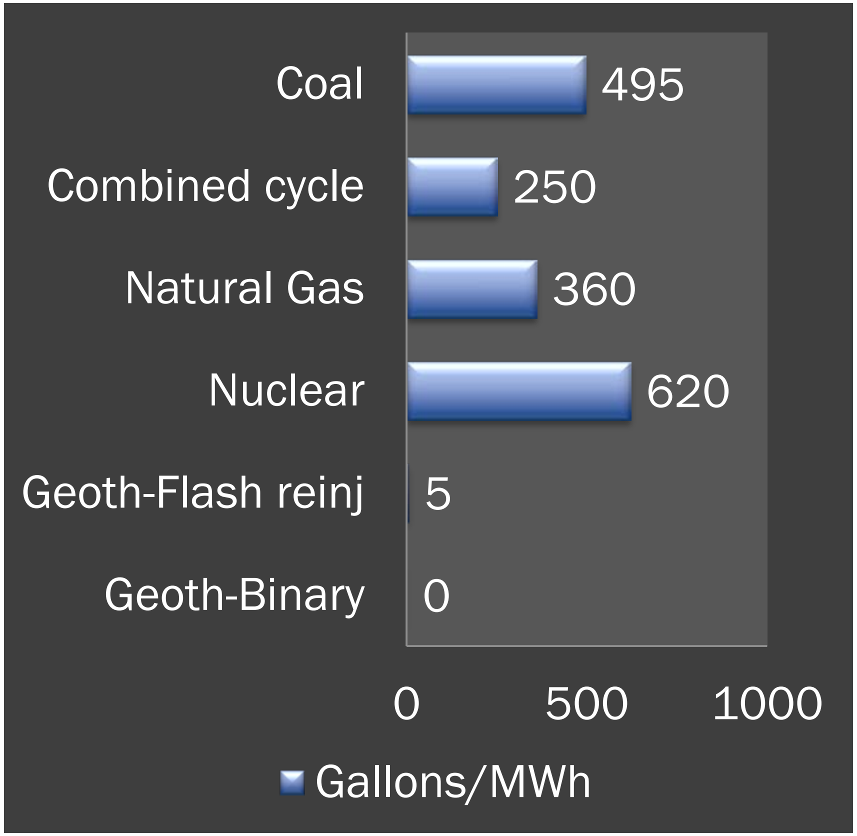
Illustration from U.S. Department of Energy; Alta Rock Energy, Inc.

Foot Print and Water Consumption

Land Use by Energy Technology



Water Use by Energy Technology



Source: Geothermal Energy Association, 2009

Power Plant Comparison: Air Emissions

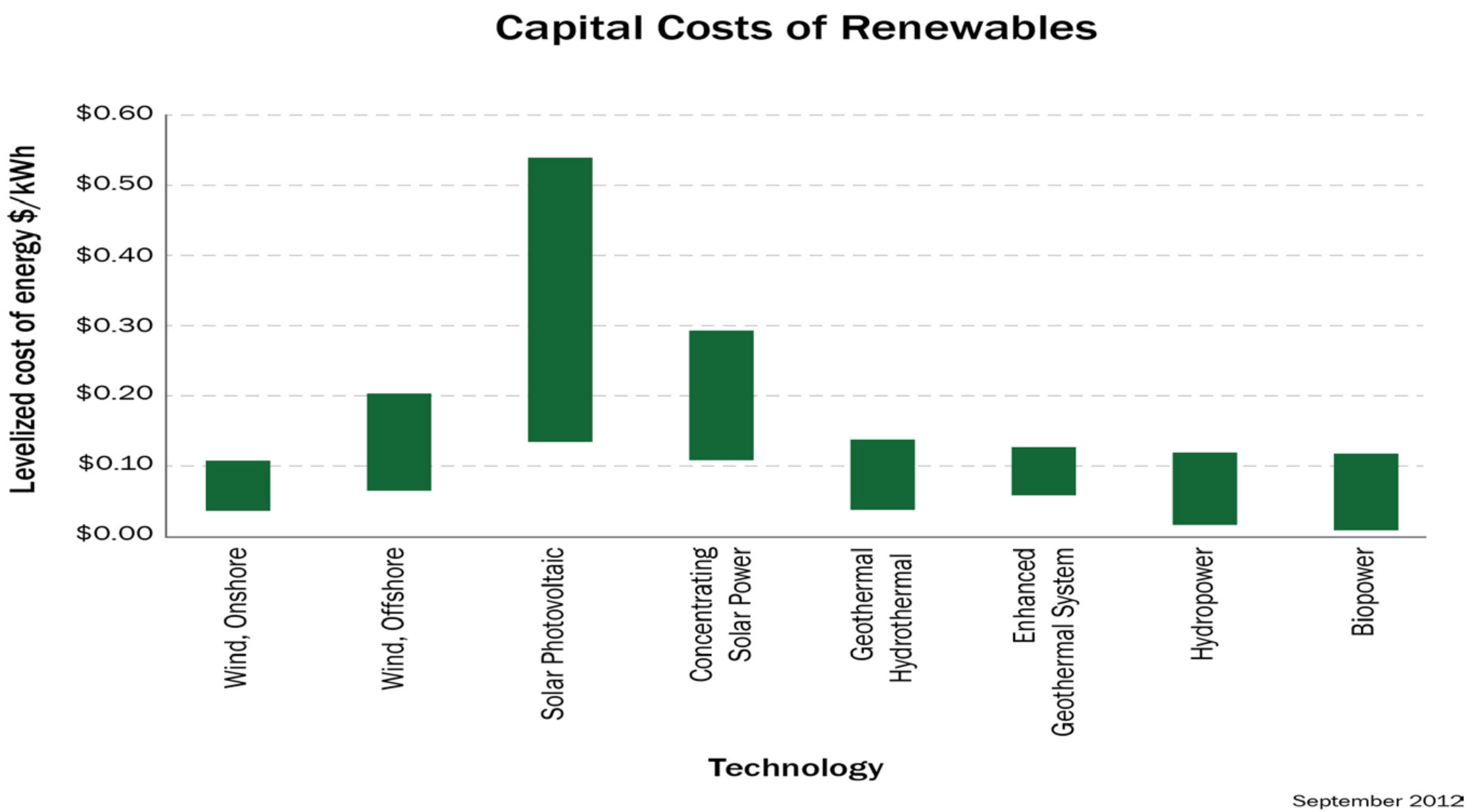
Plant Name	Year	Total MWh produced during specified year	Primary Fuel	NOx Emissions Rate (lbs/MWh)	SO_2 Emissions Rate (lbs/MWh)	CO_2 Emissions Rate (lbs/MWh)
Cherokee Station*	1997	4,362,809	Coal	6.64	7.23	2,077
Cherokee Station	2003	5,041,966	Coal	4.02	2.33	2,154
Sonoma County at The Geysers**	2003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

*Cherokee is a coal-fired, steam-electric generating station; 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.

Source: Geothermal Energy Association

Cost Comparison of Renewable Energy

Lifetime or Levelized Costs of Renewables



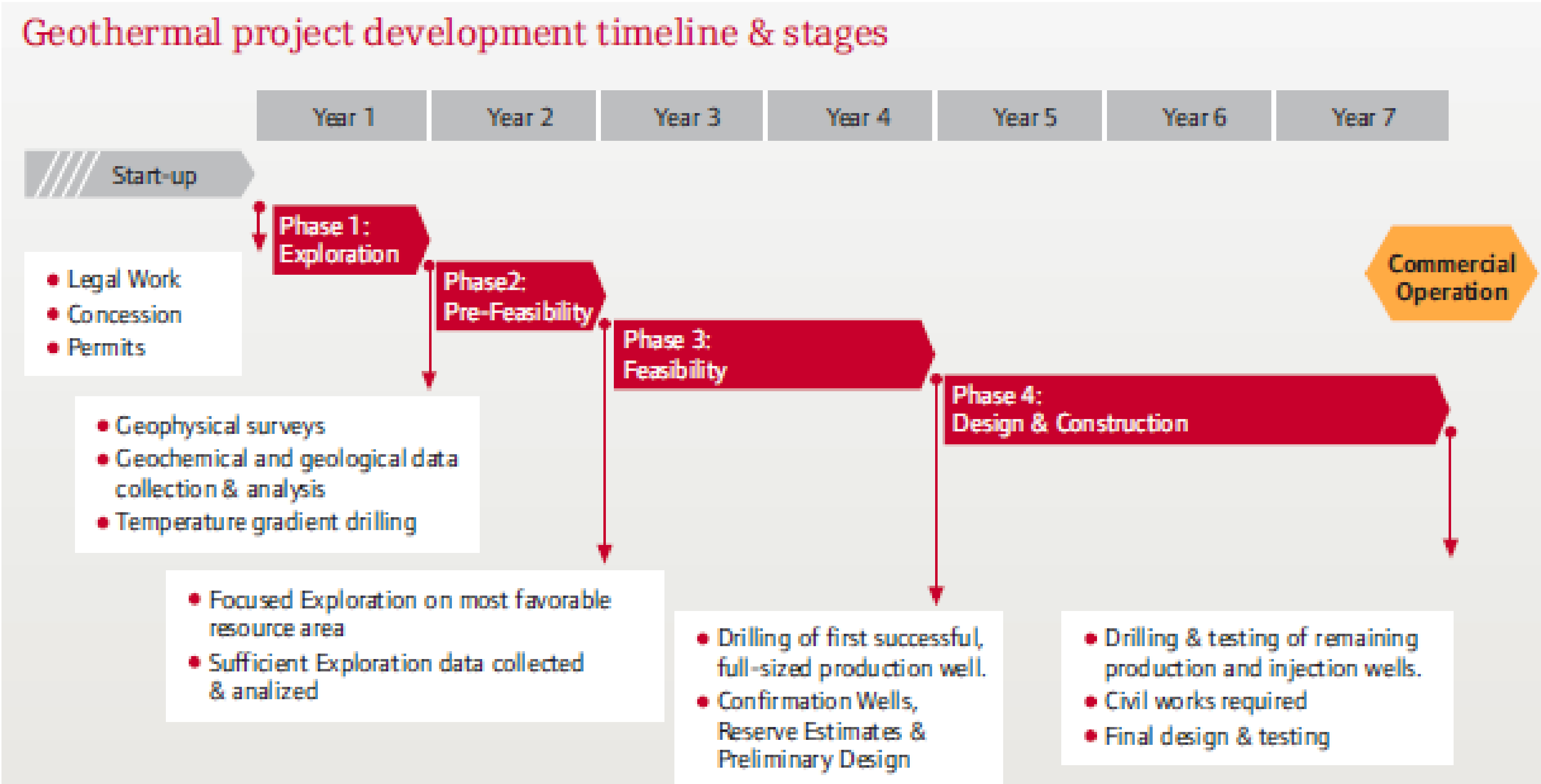
Source: http://en.openei.org/apps/TCDB/

Geothermal Cost Effective? Yes!

	Electrical Generation	Geo Exchange Systems (Geothermal Heat Pumps)		
		Residential	Commercial	Schools
Cost/Megawatt	$2,000,000 $3,000,000			
Building Size		3,000 square feet (ft^2)	7,200 (ft^2)	55,000-112,000 (ft^2)
Install Cost		$15,000 - $20,000	$408,000	$240,000 - $1,090,000
Annual Savings		$600- $1,500	$ 2,098,000	$20,000- $42,000
Cost/Ton			$1,500	$1,500

Sources: Electrical Generation: Glacier Partners, 2009: Geo-Exchange: www.geoexchange.org

Geothermal Project Development and Timeline



(US$ in millions)	Exploration	Drilling & Design	Construction	Total
Well field preparation and Exploration	10.0			10.0
Drilling cost		81.0		81.0
Transmission - connection to grid			5.0	5.0
Power Plant and gathering systems			$70.0	$70.0
Total Cost Per Phase	**10.0**	**81.0**	**75.0**	**166.0**
% of Total Cost	*6.0%*	*48.8%*	*45.2%*	*100.0%*

Source: Glacier Partners Corp, 2009

Total Projects in Development

Table 2: Total Projects in Development Totals by State

State	Total Projects	PCA (MW)	Resource (MW)	Overall Total (MW)
Alaska	6	25.4	85	90
Arizona	1	2	0	2
California	31	1065.6-1110.6	1636.7-1765.7	1859.7-2008.7
Colorado	2	20-25	0	20-25
Hawaii	3	0	0	0
Idaho	11	33.2	589-664	589-664
Louisiana	1	0.05	0	0.05
Nevada	59	631.5-641.5	1915-2125	2030.15-2250.15
New Mexico	2	15	100	115
North Dakota	1	0.25	0	0.25
Oregon	16	107.5-109.5	285-330	319.5-364.5
Texas	1	0	0.8	0.8
Utah	11	60	170-195	190-215
Washington	1	0	100	100
Wyoming	1	0.28	0	0.28
Totals*	**147**	**1961-2023**	**4882-5366**	**5317-5836**

Source: GEA

*PCA, Resource, and Overall totals have been rounded to the nearest megawatt. Also, PCA and Resource totals do not add up to Overall totals because they have been adjusted to avoid double counting. In cases where respondents gave both a PCA value and resource value, it was assumed that the PCA was already included in the stated resource total. In projects where PCA values but no Resource values were given the PCA value (being the planned capacity of the geothermal power plant) was used as the Resource value and added to the latter to get the Overall Total. As a result, the overall total is less than the sum of PCA and resource values.

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Policy Drivers, Incentives, and Programs

DOE Geothermal Technologies Program

- Instrumental in the implementation of many incentives and subsidies that offset the risk and high upfront capital cost
- Database of State Incentives for Renewable Energy (DSIRE) website: http://www.dsireusa.org/

Production Tax Credit

- Eligible power plants that are placed in service by 12/31/2013

Energy Policy Act of 2005

- Geothermal Leasing (Programmatic Geothermal Environmental Statement [PGEIS]- Lease Sales)
- Geothermal Revenue Sharing with Counties
- Section 1705 Loan Guarantees in Lieu of Production Tax Credit (PTC) ($175.6 million)

American Recovery and Reinvestment Act

- DOE Cost-Share Geothermal Investment (total $666.4 million)

Renewable Energy Portfolio Standards

Geothermal Development Process

- Lease acquisition
  - Leasing: 25 Code of Federal Regulations (CFR) 211 – leasing of tribal lands for mineral development
  - Indian Mineral Development Act (IMDA): 25 CFR 225 – Oil and gas, geothermal, and solid minerals agreements
- Exploration activities
- Drilling production and injection wells
- Utilization
  - Power plants
  - Direct use facilities
- Abandonment of wells and facilities
- Reclamation of surface

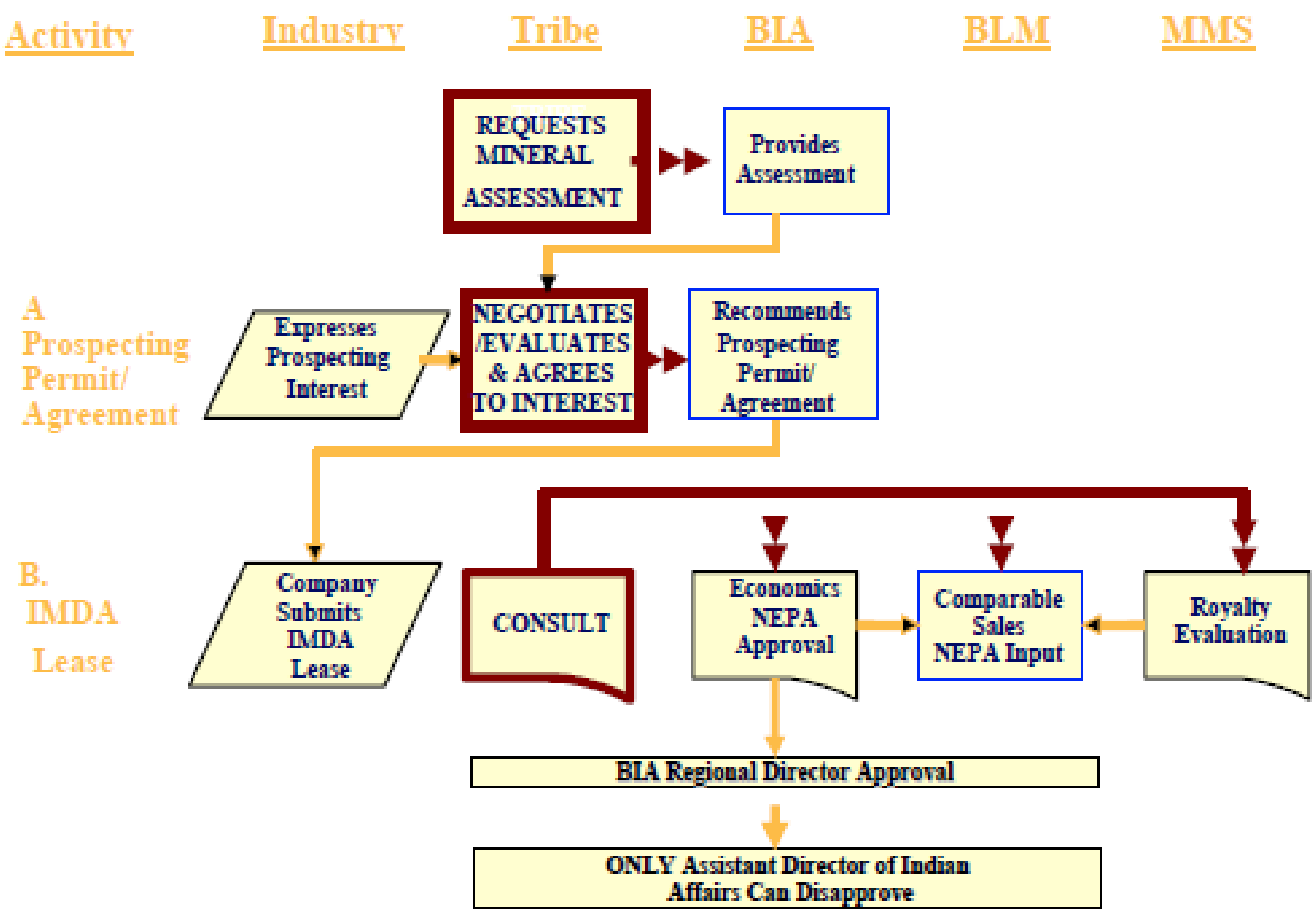
Geothermal Development Process





Sources (clockwise): NREL/PIX 13083, 17038, 13995, 17555, 16814, 13093

IMDA Process



Source: California Geothermal Energy Collaborative, 2006 California Tribal Workshop

What we covered…

▪	About the DOE Office of Indian Energy Education Initiative	√
▪	Course Introduction (Takeaways)	√
▪	Resource Map & Project Scales	√
▪	Technology Overview(s):	√
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	- Costs	√
▪	Successful Project Example(s)	√
▪	Policies Relevant to Project Development	√
▪	Additional Information & Resources	

Useful Resources

RESOURCE

- NREL geographic information system (GIS) maps: http://www.nrel.gov/gis/maps.html
- NREL geothermal: http://www.nrel.gov/gis/geothermal.html

TECHNOLOGY

DOE Geothermal Technologies Program:
http://www1.eere.energy.gov/geothermal/faqs.html

POLICY

- Western Area Power Administration: http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf
- IMDA: 25 CFR 225 and Leasing: 25 CFR 211

Thank You & Contact Information

For Technical Assistance:
IndianEnergy@hq.doe.gov.

DOE Office of Indian Energy Website:
www.energy.gov/indianenergy

NREL Technology Websites:
www.nrel.gov/learning/re_basics.html

Kermit Witherbee
Geothermal Energy Geologist/Analyst
kermit.witherbee@nrel.gov

INFORMATION ON THE CURRICULUM PROGRAM & OFFERINGS

Curriculum Structure & Offerings

Foundational Courses

- Overview of foundational information on renewable energy technologies, strategic energy planning, and grid basics

Leadership & Professional Courses

- Covers the components of the project development process and existing project financing structures

Foundational Courses

Energy Basics

- Assessing Energy Needs and Resources
- Electricity Grid Basics
- Strategic Energy Planning

Renewable Energy Technology Options

- Biomass
- Direct Use
- Geothermal
- Hydroelectric
- Solar
- Wind

All courses are presented as 40-minute Webinars online at
www.energy.gov/indianenergy