

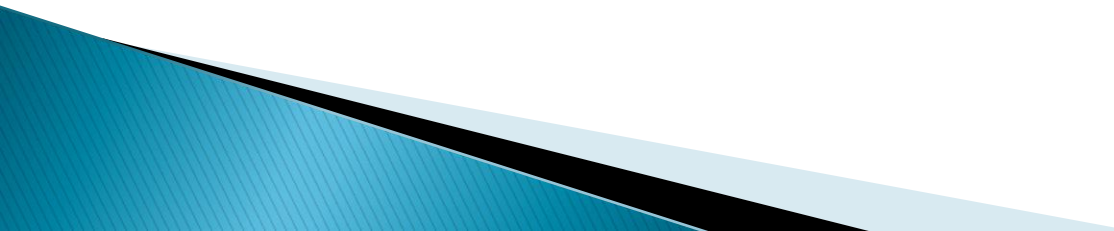
Geothermal Energy

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Current News

- ▶ http://www.denverpost.com/breakingnews/ci_13743131
- ▶ http://www.gjsentinel.com/hp/content/news/stories/2009/11/07/110809_1A_Geothermal_leases.html
- ▶ Colorado resource map
 - <http://geothermal.inel.gov/maps/co.pdf>

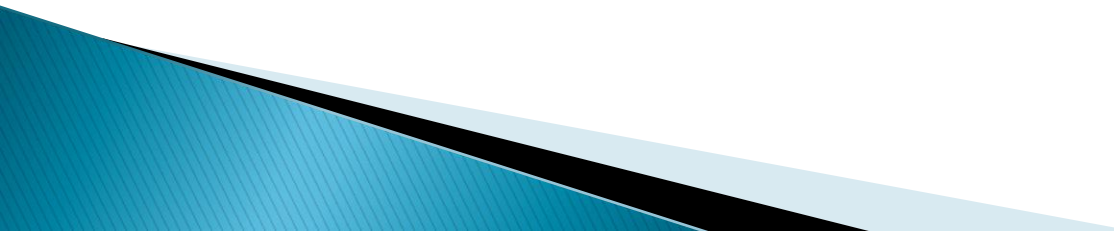
Introduction

- ▶ Geothermal– Earth heat
 - ▶ Production of electric energy by use of sub-surface hot water reservoirs
 - ▶ Wells drilled to appropriate depth
 - ▶ Hot water or steam is brought to the surface
 - May require additional heating
 - ▶ May be used for space heating and cooling
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Resources

- ▶ Hot water reservoirs
 - Heated underground reservoirs
- ▶ Natural steam reservoirs
 - Ground steam
- ▶ Geo-pressured reservoirs
 - Sub-surface salt water compressed due to weight of overlaying material
- ▶ Geothermal gradients
 - Drilled shafts allowing access to dry hot rock
 - +30°C for every km drilled
- ▶ Molten magma
 - Not suitable for energy extraction

Geothermal Extraction Potential

- ▶ Based on the temperature of the material
 - How deep is the access?
 - What is the volume of the material?
 - ▶ What are the temperature requirements?
 - ▶ Then, based on the amount of material and the temperature, how long will the source generate?
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Dry Steam Plants

- ▶ Uses very hot water and steam to turn turbines
 - Steam may be depressurized and cleansed of CO₂, Sulfur, and nitric oxide
 - Results in 2% of pollution of a normal fossil plant
- ▶ https://inlportal.inl.gov/portal/server.pt?open=512&objID=422&&PageID=3453&mode=2&in_hi_userid=2&cached=true
- ▶ http://www.digtheheat.com/geothermal/dry_steam_plant.html

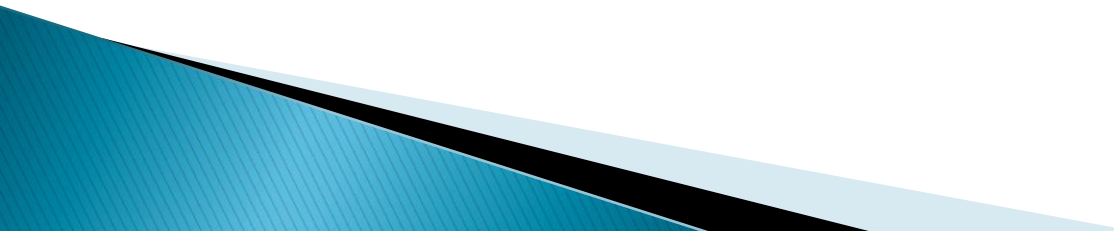
Binary Plants

- ▶ Geothermal steam is extracted, passed through a heat exchanger
- ▶ Secondary fluid with lower boiling temp is vaporized and used to turn turbines
 - Secondary fluid is then re-used
- ▶ Geothermal fluid is condensed and returned to a reservoir
- ▶ Closed cycle, no emissions
- ▶ <http://www.superstitionmountaineis.com/images/GeothermalProcessRevised.pdf>
- ▶ <http://www.superstitionmountaineis.com/images/BinaryDiagram.pdf>

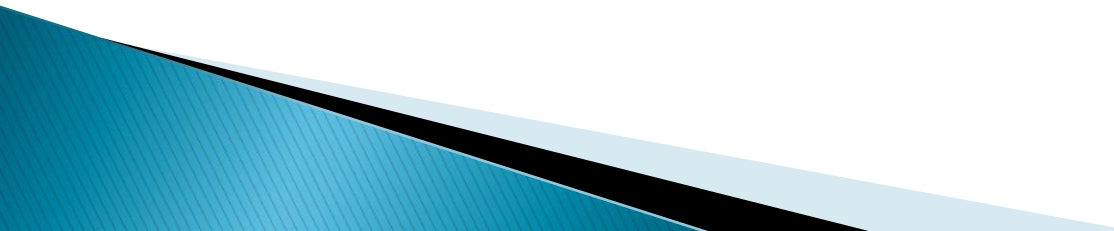
Flash Steam Plants

- ▶ Hot, highly pressurized water is pumped to the surface
- ▶ Pressure is quickly dropped, producing steam
- ▶ Spent water is returned
- ▶ http://www.digtheheat.com/geothermal/flash_power_plant.html

Geothermal Potential

- ▶ Must have the appropriate subsurface characteristics to be feasible
 - ▶ California, Pacific N.W., Idaho, Colorado
 - Pacific NW potential – 1.3 million homes
 - ▶ Systems have been in used since 1904
 - ▶ Hawaii – 25% of electricity from geothermal
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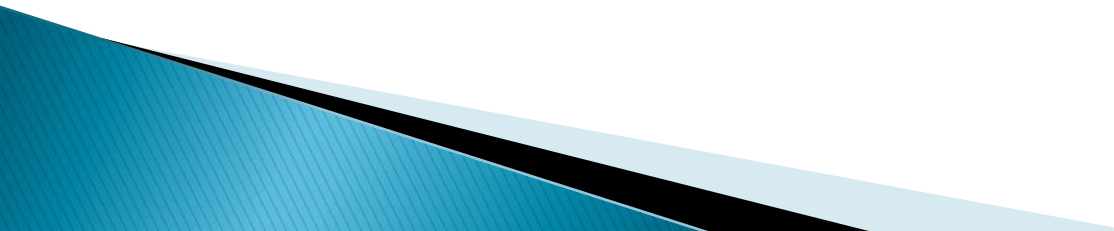
Geothermal Costs

- ▶ Typical cost per kWh is 4.5–7 cents
 - Comparable to coal, natural gas
 - Much less pollution produced, resulting in few environmental costs
 - ▶ Capital intensive plants
 - ▶ Typical payback is around 15 years
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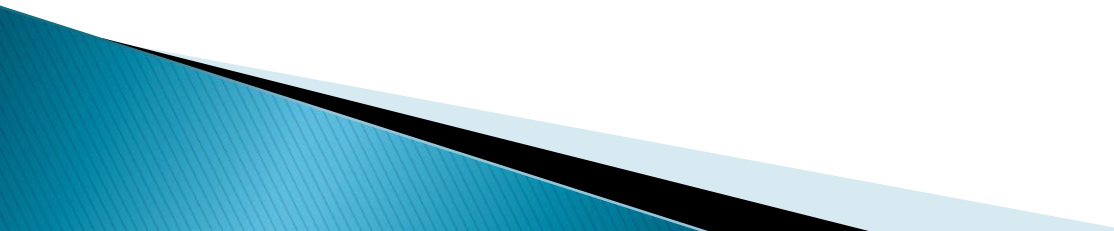
Environmental Impact

- ▶ Generally one of the lower polluting power sources
- ▶ Condensed water is re-injected back into the ground
 - Potential to cool nearby hot springs
 - Intermixing with groundwater must be prevented
- ▶ Some CO₂ is produced, but 15–20x less than the cleanest fossil plants

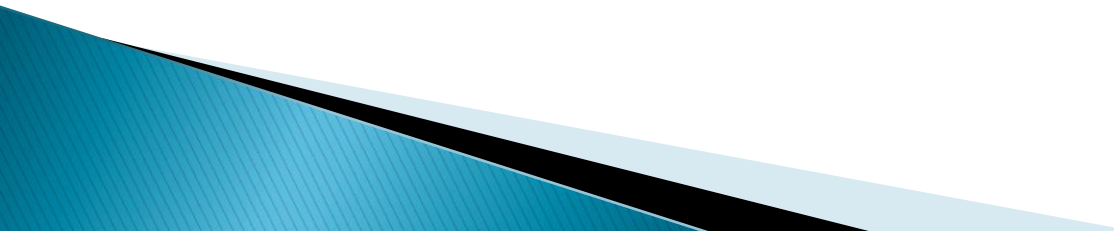
Benefits

- ▶ Clean energy source
 - ▶ Uses little space
 - ▶ Sustainable and renewable energy
 - ▶ Continuous and reliable power supply
 - ▶ Cost competitive
 - ▶ Conserves fossil fuel, reduces imports
 - ▶ Modular power plants can incrementally be increased in size
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Advantages

- ▶ Minute amount of fumes generated during drilling
 - ▶ Can be used for electricity, hot water heating, industrial drying
 - ▶ Reliable and constant source of power (versus wind or solar)
 - ▶ Geothermal power generation is around 97% efficient, turbine friction losses
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Disadvantages

- ▶ Must have proper location
 - ▶ Source may run out of steam or hot water
 - ▶ Extraction can release hazardous materials into the atmosphere (Hydrogen sulfide)
 - ▶ Earthquake possibility
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More Information

- ▶ Geothermal plants and the environment
 - <http://www.geo-energy.org/Publications/reports/Guide%20to%20Geothermal%20Energy%20and%20Environment.pdf>

Geothermal Heat Pumps

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Introduction

▶ Sources

- <http://www.geoexchange.org/resources/videos/videowvideo/1.html>
- http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640
- http://www.consumerenergycenter.org/home/heating_cooling/geothermal.html
- <http://www.geothermalheatpump.com/how.htm>

▶ Heat pumps

- http://www.istc.illinois.edu/main_sections/tech_assist/geothermal-systems.pdf

Sensible and Latent Heat Gains

- ▶ Latent heat gain can have a significant influence on the total cooling load
- ▶ Sensible heat gains– change in temperature
 - Heat transmission through opaque assemblies
 - Solar heat gain through transparent or translucent materials
 - Leakage of outside air through the building envelope
 - Ventilation air
 - Occupants
 - Lights, equipment, appliances
- ▶ Latent heat gains– heat associated with a phase change
 - Addition or loss of moisture to a space
 - Moisture laden outside air from infiltration and ventilation
 - Occupant respiration and activities
 - Moisture from equipment and appliances

Latent Heat Example

- ▶ It takes one BTU to heat 1 pound of water 1° F
 - To raise the temperature of 1 pound of water 180° would take 180 BTU
 - So 32 to 212 = 180 BTU
- ▶ It takes 970 BTU to change one pound from water to steam
 - So, for 1 pound of water from water at 212 to steam at 212 = 970 BTU
- ▶ Heat of fusion – 144 BTU / lb of water
- ▶ Heat of vaporization – 970 BTU / lb of water

Refrigeration Capacity

- ▶ Ton of refrigeration (ton)– 12,000 Btu/hr
- ▶ The cooling effect of one ton of ice over the course of one day
 - Latent heat of fusion for ice is 144 BTU/lb
 - $144\text{BTU} * 2000\text{ lb/ton} = 288,000\text{BTU}$ over the course of one day or 12,000 BTU / hr

Basics

- ▶ Take advantage of the steady below-grade temperature
 - Indoor unit, buried loop
- ▶ Used for heating and cooling
- ▶ Do not burn fossil fuel for heating
 - Electric power to operate the unit's fan, compressor, pump
- ▶ Refrigeration cycle
 - <http://www.air-conditioning-and-refrigeration-guide.com/refrigeration-cycle.html>

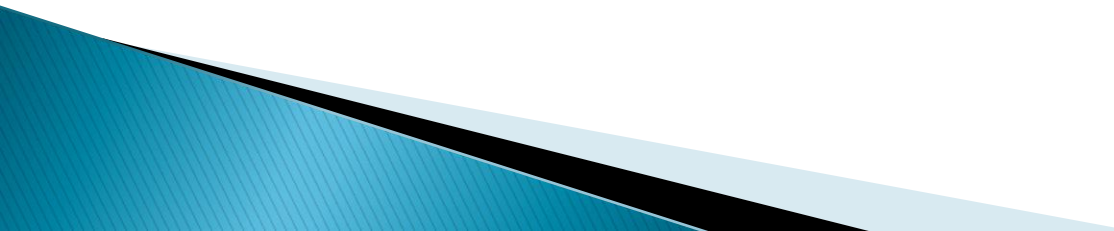
Components

- ▶ Liquid heat exchange medium
 - Closed or open loop
- ▶ Heat pump unit
- ▶ Air delivery system
 - Ductwork

Coefficient of Performance

- ▶ COP–
 - Measurement of the amount of heat produced compared to what is input
 - Forced air furnace– 70–90+ % efficiency
 - Geothermal heat pump–
 - COP 3–5
 - $COP_{heating}$ 3.5 provides 3.5 units of heat for each unit of energy consumed (e.g. 1 kWh consumed would provide 3.5 kWh of output heat)

Open Loop

- ▶ Uses ground water from a well, lake, or stream for heating and cooling
 - ▶ Must be environmentally safe
 - ▶ No environmental damage
 - ▶ Water must be discharged
 - Will have environmental regulations
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Closed Loop

- ▶ Uses a continuous loop of buried polyethylene pipe
- ▶ Connected to the indoor heat pump
- ▶ Environmentally friendly anti-freeze and water solution is circulated
- ▶ Can use a horizontal or vertical circulation loop
 - Trenches 6'x400' depending on piping
 - 500–600' /ton of capacity
 - 3 tons of cooling per typical house

Vertical Closed Loop

- ▶ Holes can be bored (up to 250' per ton of cooling)
 - U-shaped pipes are inserted in the holes and backfilled
- ▶ Polyethylene pipes can have decades of useful life

Geothermal Considerations

- ▶ What are the local ordinances / codes?
 - Covenants?
 - ▶ Dual fuel systems are a possibility
 - ▶ Easier to install when new, but can be retro-fit
 - House should have existing ductwork
 - ▶ Should not have to alter existing ductwork or electrical service
 - ▶ Heating load assessment is a good first step
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