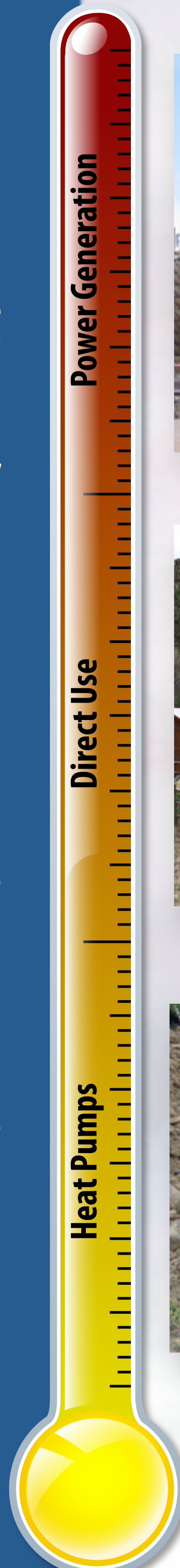
Using Geothermal Energy to Comply with EPA's Clean Power Plan



A State guide to understanding the potential of geothermal technology to reduce state electricity and energy sector emissions

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Geothermal Resources Council

Geothermal Exchange Organization

Geothermal Energy Association

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Executive Summary

On August 3, 2015, President Obama and Environmental Protection Agency (EPA) announced a federal Clean Power Plan. The Clean Power Plan (CPP) creates a flexible framework for state control of strategies for reducing carbon pollution -- the largest contributor to global climate change and the cause of an array of public health problems. Under the CPP, geothermal technologies are eligible in a "Best System of Emission Reduction" (BSER) strategy. Where suitable geothermal resources are available, states can build geothermal power plants, and expand direct uses of geothermal heat. And geothermal heat pumps can contribute to demand-side energy efficiency programs in every state.

Fossil fuel power plants are the largest source of carbon to our atmosphere. Geothermal resources suitable for generating electricity, primarily found in the Western United States (U.S.), can be extremely valuable sources of clean, reliable power. Geothermal energy provides a firm but flexible generation resource in a power supply market flooded with other renewable, but intermittent, generation technologies. In addition to providing a secure indigenous supply of electricity, transmission system reliability, and a low-cost fixed price of power, geothermal plants have very low to nonexistent carbon emissions. In California, for example, The Geysers and Imperial County geothermal plants supply baseload electricity while offsetting the emissions of 11.6 billion pounds of carbon dioxide annually that would otherwise be emitted by fossil fuel plants. That is equivalent in greenhouse gas emissions to taking more than 1,050,000 cars off the road.

Direct-uses of heat and hot water from geothermal resources can be used for a number of purposes as demand-side efficiency technologies, including cooking, pasteurizing, space heating, biofuel production, soil warming, heating and cooling, vegetable drying, snow melting and deicing, lumber or cement drying, pulp and paper processing, aquaculture, soil sterilization, fabric drying, refrigeration or ice making, and greenhouse heating. Using direct-use geothermal systems for these commercial purposes instead of fossil fuels helps states further reduce emissions.

Lastly, geothermal heat pumps (GHPs), also known as ground-source heat pumps, use the near-constant temperatures and the insulating properties of the Earth just a few feet underground and do not require accessing a deep geothermal reservoir. GHPs are among the most efficient and comfortable heating and cooling technologies currently available and their use is burgeoning nationwide. Energy Star-certified geothermal heat pumps are over 45 percent more energy efficient than traditional systems powered by fossil fuels. Geothermal Heat Pumps are clean, quiet, create no indoor pollution, and use 25% to 50% less electricity than conventional heating or cooling systems.

The policy and regulatory structures discussed more fully in this document can speed implementation of these geothermal technologies to cost-effectively achieve state CPP carbon reduction and other state clean air program goals.

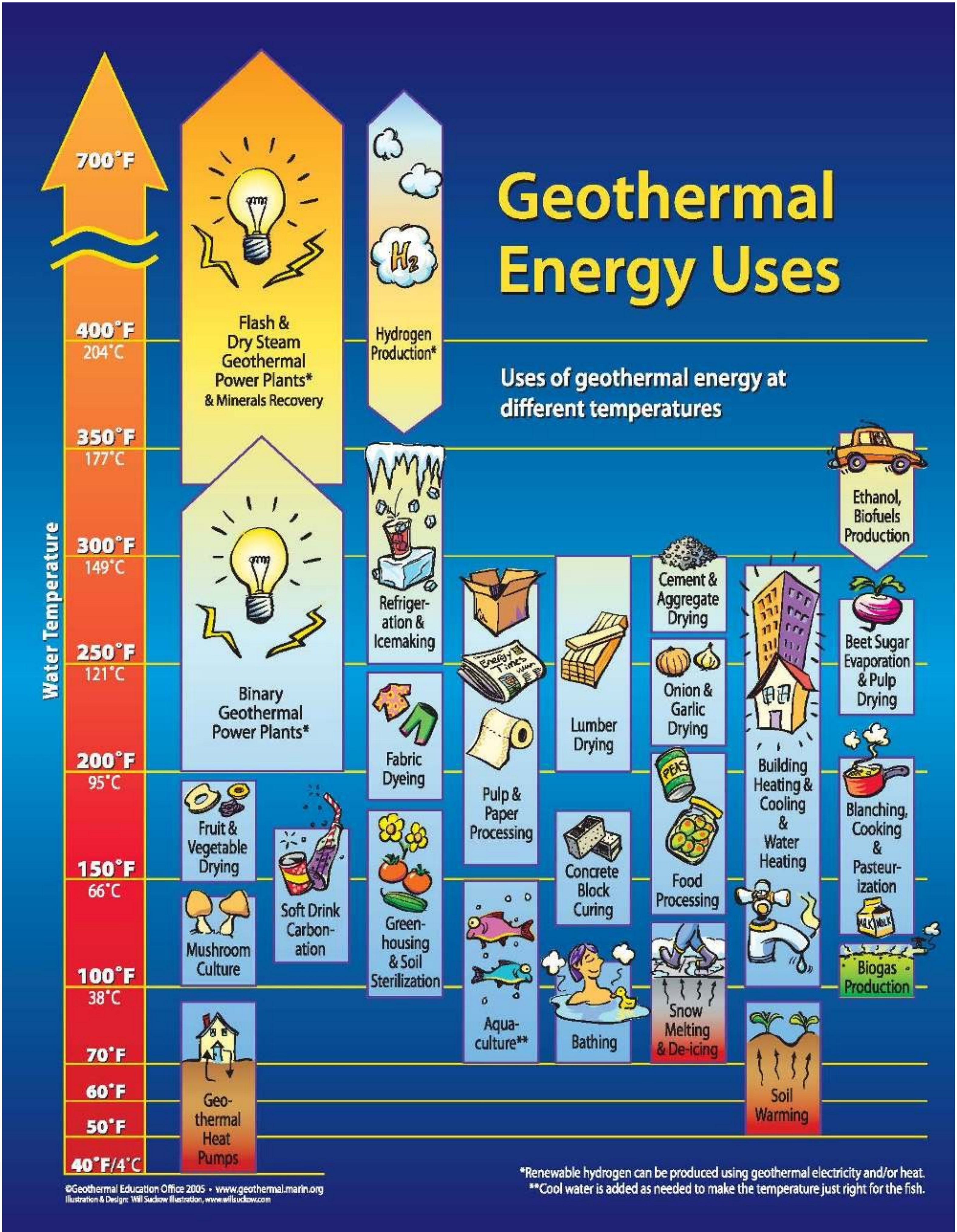
Geothermal Energy Uses
Uses of geothermal energy at different temperatures
Water Temperature
700°F
400°F 204°C
350°F 177°C
300°F 149°C
250°F 121°C
200°F 95°C
150°F 66°C
100°F 38°C
70°F
60°F
50°F
40°F/4°C
Flash & Dry Steam Geothermal Power Plants* & Minerals Recovery
Hydrogen Production*
H2
Binary Geothermal Power Plants*
Refriger-ation & Icemaking
Fabric Dyeing
Green-housing & Soil Sterilization
Fruit & Vegetable Drying
Soft Drink Carbon-ation
Mushroom Culture
Geo-thermal Heat Pumps
Pulp & Paper Processing
Energy Times
Aqua-culture**
Lumber Drying
Concrete Block Curing
Bathing
Cement & Aggregate Drying
Onion & Garlic Drying
Food Processing
PEAS
Snow Melting & De-icing
Building Heating & Cooling & Water Heating
Soil Warming
Ethanol, Biofuels Production
Beet Sugar Evaporation & Pulp Drying
Blanching, Cooking & Pasteur-ization
MILK MILK
Biogas Production
*Renewable hydrogen can be produced using geothermal electricity and/or heat.
**Cool water is added as needed to make the temperature just right for the fish.
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Illustration & Design: Will Suckow Illustration, www.willsuckow.com

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Introduction

On August 3, 2015, President Obama and the Environmental Protection Agency (EPA) announced the Clean Power Plan. The Clean Power Plan will reduce carbon pollution from power plants, the nation's largest source of carbon pollution that leads to an array of public health problems and exacerbates global climate change. On the same date, the EPA issued final Carbon Pollution Standards for new, modified, and reconstructed power plants and proposed a Federal Plan and model rule to assist states in implementing the Clean Power Plan. These are the first-ever national standards that address carbon pollution from power plants.

Under the Clean Power Plan, states must develop and implement plans to comply with these rules to ensure the power plants within their state meet their state-specific goals for carbon pollution by 2030. Throughout the U.S., geothermal energy is an excellent way to comply with EPA's carbon reduction goals. Tapping into energy generated from the earth's crust is a clean, emission free and reliable way to generate electricity at economical rates across the U.S. with minimal impact to the environment.

To comply, states may choose between two types of plans. Targets are expressed as either emission rate or mass of CO_2 reduced.

- Emission standards plans include source-specific requirements ensuring all affected power plants within the state meet their required emission performance.
- State measures plans include a mixture of measures implemented by the state, such as renewable energy standards and programs to improve residential energy efficiency that are not already included as federally enforceable components of the plan.

In both plan types, states can use geothermal resources outlined in the Best System of Emission Reduction (BSER) by building power generation facilities where these plants are available or by implementing direct use and geothermal heat pump demand-side energy efficiency programs.

If states are to choose demand-side efficiency measures, geothermal direct-use and heat pumps are an excellent option for reducing consumption of electricity for heating and cooling. Geothermal heat pumps are cost-effective and proven technologies that reduce the need for more carbon-intensive fuels to cool or heat homes and businesses.

When low-temperature geothermal resources are available, geothermal direct-use technology can be used for cooking, pasteurizing, space heating, biofuel production, soil warming, heating and cooling, vegetable drying, snow melting and deicing, lumber or cement drying, pulp and paper processing, aquaculture, soil sterilization, fabric drying, refrigeration or ice making, and greenhouse heating.

The number of states that have high-temperature geothermal resources at economical depths capable of generating electricity are more limited. In general, there are three types of geothermal power conversion technologies, dry steam, flash, and binary (or organic Rankine cycle).

Dry Steam Plants: In dry steam plants, naturally occurring, high-pressure steam shoots up from the dry steam reservoir and used to run the turbines that power the generator.

Flash Plants: In flash plants, steam is separated from high-pressure and high-temperature geothermal fluids (hot water and steam). The steam is delivered to a turbine that powers a generator. The liquid (condensed from the steam after passing through the turbine) and remaining geothermal water are injected back into the reservoir.

Binary Plants: In binary or ORC (i.e., organic Rankine cycle) plants, the heat is transferred from the hot water to an organic working fluid that has a boiling point lower than the boiling point of water. The working fluid is vaporized to run the turbine. The geothermal water is never allowed to reach the atmosphere - 100% is injected back into the reservoir. In all systems, the injected fluid is never allowed to mix with the shallow groundwater system. For illustrations of these types of technologies please see Appendix A.

All of these geothermal systems can be included as part of EPA's Clean Power Plan and will be essential for meeting carbon reduction targets across the U.S. Geothermal energy is estimated to currently supply 75,862 terrajoules per year (TJ/yr), or 21,074 gigawatt-hours per year (GWh/yr) of heat energy in the U.S. from direct heat uses and geothermal (ground-source) heat pumps. The total low temperature, heat resource capacity of the U.S. is estimated to exceed 17.5 gigawatts thermal (GW_t).[1]

For geothermal resources capable of producing electricity, the United States Geological Survey (USGS) estimates there are over 9 GW_e of identified resources, and over 30 GW_e of unidentified resources across 13 western states.[2] If Enhanced Geothermal Systems (EGS), co-production, and geo-pressured systems are included, these estimates expand to another dozen states and nearly quadruple. In places such as California, geothermal power already contributes substantially to state climate goals. For example, the Geysers and Imperial County, California geothermal plants supply baseload electricity while offsetting the emissions of 11.6 billion pounds of carbon dioxide annually that would otherwise be emitted by fossil fuel plants. That is equivalent in greenhouse gas emissions to taking more than 1,050,000 cars off the road.[3]

[1] Boyd, et al., 2015.
[2] Williams, et al., 2008
[3] McGuire, et al., 2015.

Section 1

Geothermal Electricity

Environmental & Emission Benefits

Geothermal power generates extremely low emission rates, especially when compared with traditional fossil fuels that involve direct combustion of fuels. Binary power plants, which represent most of the geothermal plants that have come online recently, have near-zero greenhouse gas emissions and minimal particulate matter emissions.[4] When considering life cycle emissions, Argonne National Laboratory found binary geothermal power plants to be one of the cleanest forms of energy.[5] Flash and dry steam geothermal power plants also represent a significant improvement over coal and natural gas, as shown in Table 1.[6] In general, emissions from geothermal plants, when they do occur, are several orders of magnitude less than those of fossil fuel facilities.

Within the U.S., geothermal plants are usually found in regions of tectonic and volcanic activity and can be co-located with natural hot springs and similar manifestations that naturally release greenhouse gases. The naturally occurring emissions from these from these features often exceeds those from the geothermal plants.[7]

Table 1: Estimated Emission Levels by Pollutant and Energy Source of Power Plants[8]

[lbs/MWh]	Dry Steam*	Flash*	Binary	Natural Gas*	Coal*
CO_2	60	396	0	861	2200
CH_4	0	0	0	0.0168	0.2523
$PM_{2.5}$	0	0	0	0.1100	0.5900
PM_{10}	0	0	0	0.1200	0.7200
SO_2	0.0002	0.3500	0	0.0043	18.75

*Note: These estimates are for a typical California geothermal power plant. The fossil fuel emission estimates are for a typical fossil fuel fired power plant in the U.S.

The emission most frequently associated with geothermal power production is hydrogen sulfide (H_2S), a gas that occurs naturally in varying concentrations in geothermal systems. H_2S oxidizes into sulfur dioxide and sulfuric acid when released into the atmosphere. Known for its distinctive "rotten egg" smell, hydrogen sulfide is a natural component of many volcanic and geothermal systems. Today, hydrogen sulfide abatement systems, such as LO-CAT and Stretford, are used extensively throughout the industry and have demonstrated a removal efficiency of more than 99.9%[9]. Through such systems, hydrogen sulfide is converted to elemental sulfur, which can be used as a feedstock for fertilizers or as a soil amendment.

Not only are emissions minimal to non-existent but the land footprint is tiny as well. Geothermal power uses very little land compared to other energy sources, particularly when weighed against other renewables. Unlike power generated from solar, wind, and biomass sources, which are predicated upon gathering diffuse ambient energy over large tracts of land,

4 (Matek, 2013)
5 (Sullivan & Wang, 2013)
6 (Matek, 2013)
7 (Bertani & Thain, 2002)
8 (Matek, 2013)
9 (Nagl, 2009)

geothermal exploits a concentrated, subterranean resource. Geothermal plant facilities use less surface area for comparable levels of power.

A recent paper estimates the intensity of land use associated with various energy sources based on the anticipated state of technology in the year 2030. Assuming 8,766 hours in a year, geothermal power's estimated use of 66 km^2/GW is lower than coal (85), solar thermal (134), natural gas (163), solar voltaic (323), petroleum (392), hydropower (473), wind (632), and biomass (4,760).[10] Geothermal resources do not require transportation of fuels long distances by pipeline, highway, rail, or across oceans in tankers. They are homegrown resources with power plant facilities located at the reservoir site supplying electricity to regional grids.

Employment & Economic Benefits

- Geothermal plant construction employs about 3.1 person-years per MW; the manufacturing of the equipment requires an additional 3.3 person-years per MW.
- Geothermal power plants employ about 1.17 persons per MW at each operating power plant. These are permanent jobs that last the entire 30-50 year lifetime of the power plant.
- In total, adding governmental, administrative, and technical related jobs, the geothermal industry employs about 2.13 persons per MW.
- An average 50 MW facility will create permanent employment for about a 100 people.
- In 2013, U.S. geothermal power producers paid $29 million dollars in annual property taxes, including $21 million dollars to the State of California alone.
- Geothermal paid about $26 million in rents and royalties to state, federal and local governments nationwide in 2014 of which one quarter is returned to benefit state and local county governments.
- Over the course of 30 to 50 years an average 20 MW facility will pay nearly $6.3 to $11 million dollars in property taxes.

Firm & Flexible Power Potential

With well-structured and appropriately priced contracts, geothermal plants can provide both flexible and baseload power production. Although traditionally operated as a source of baseload power, the advancement of power plant and control technology allow geothermal power plants to work in several different modes, such as grid support, regulation, load following, spinning reserve, non-spinning reserve, and replacement or supplemental reserve. These modes are commonly referred to as "ancillary services," which are performed by entities that generate, control and transmit electricity in support of the basic services of generating capacity, energy supply and power delivery. The future electricity grid, dominated by variable energy resources (primarily wind and solar), will need technologies that can be both baseload and flexible.

[10] (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009)

While most geothermal plants generate baseload electricity, flexible geothermal operations have been demonstrated at several projects, including the Puna Geothermal Venture plant in Hawaii which generates 38 MW, and has contracted 16 MW of flexible capacity. This plant provides ancillary services for grid support that are identical to those of the existing oil-fired peak generating resources on the Big Island. This plant is considered a first-of-its-kind and could be expanded to other facilities given the right contracts and retrofits.[11] Additionally, geothermal plants at the world's largest geothermal field – The Geysers, located in northern California – have operated in various modes, including traditional baseload, peaking and load following. The flexible modes were offered as an appropriate response to the needs of one of the utilities purchasing geothermal power from The Geysers. Flexible operations ceased in the early 1990s in response to a combination of low demand and lower costs of generation within the utility's system from hydro, coal, and natural gas power plants.[12]

In general, it's currently more economical for geothermal developers to operate geothermal plants under baseload power purchase agreements for their plants. However, some suggestions in the geothermal industry on how to respond to utilities recent call for geothermal power to be supplied in more flexible contracts include the following:

- Utilities could buy capacity from a geothermal plant and then purchase energy as they regulate its output, within the plant's technical limits. Flexible contracts with pricing structures that account for geothermal energy's unique capital structure would enable flexible geothermal power to compete with natural gas.
- Utilizing storage technologies for geothermal power plants to store power and release the electricity as needed, instead of constantly exporting electricity directly to the grid.[13]
- Ancillary services in the past have traditionally been provided by fossil fuel sources such as natural gas. In many cases these contracts are very highly priced due to spot market gas purchases. Renewables can offer a more economical alternative, since there is no volatility in fuel pricing.

Cost of Geothermal Power

Project Cost

The cost of a typical geothermal power project is highly dependent on several factors including drilling depth, geology, temperature and project size. However, a typical 50-MW greenfield project in a geothermal field with wells of around 2 km (6500 ft) in depth will cost between 2.8 - 5.5 million US $/MW. This includes the cost of everything from preliminary surveys to turbine construction.[14] A typical new 25-35 MW project in the U.S. costs between $125 -150 million.

A common practice is to build existing projects incrementally, either by adding more wells and more turbine generator modules to an existing (brownfield) power project, or adding a "bottoming cycle" unit to the plant using existing wells. The advantage of this development

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[11] (Nordquist, et al., 2013)
[12] (Cooley, 1996)
[13] (McGrail, 2015)
[14] (Gehringer & Loksha, 2012)

approach is that it improves the sustainability of the reservoir and is often a lower cost way of building geothermal projects. If built in this manner, projects fall on the lower end of the spectrum often ranging from 1.5-4 million US $/MW.[15]

Power Purchase Agreements

Data collected by GEA and the US DOE Geothermal Technology Office (DOE) shows that projects in the U.S. have signed power purchase agreements (PPAs) with utilities in the last ten years typically ranging between $17.76 - $101.95 per MWh. These power purchase agreements are normally for base-load power contracts. The low-end price was for an older, existing facility and is likely based on California's Short Run Avoided Cost. The high-end prices are for newer binary projects that were built on lower-temperature resources that were smaller in size.

Recommended Geothermal State Policies & Practices

For any state utilizing geothermal energy or direct use to comply with EPA's 111(d) Clean Power Plan, the GEA recommends the following practices be implemented to ensure smooth and expedient development of the technology.

Research & Risk Reduction

- Publish public exploration data in the public domain for companies to use and verify.
- Initiate action to develop resource information, either as donors or governments.
- Donors and governments (both national and local) may need to participate in drilling risk.
- Support research in energy storage schemes to further enhance grid stability while creating a good economic environment for geothermal and other renewables.

State Agency Policy & Law

- Coordinate institutions into what is effectively one body governing geothermal resource development.
- Minimize the number of agencies or institutions involved with regulation—"one-stop shopping" is the ideal model.
- Develop institutional capacity and capability.
- Develop laws and regulations that create an investment environment where risk and return are matched for geothermal development.
- Developers who make significant investments or resource discoveries on state lands under exploration permits should have a right to a negotiated lease, or right of matching high bids under public auctions.
- Developers of public lands should have a limited time to act on permits, or leases can terminate.

Public Utility Commissions, Contracts & the Market

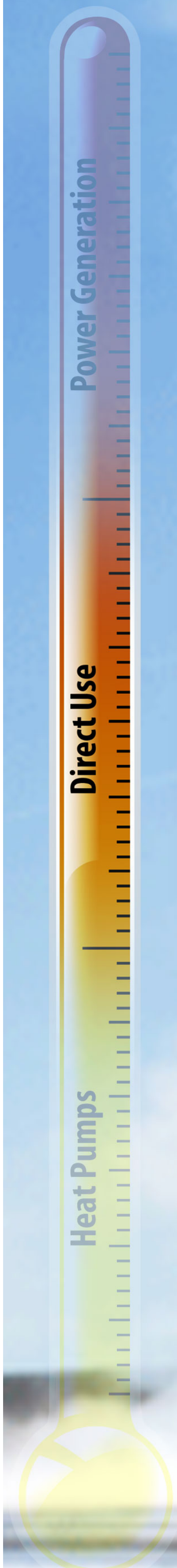
- Take the current electricity market into account. There must be a market for the electricity. Generation growth must be accompanied by grid growth.

[15] Unpublished GEA & DOE data.

- Promote the use of demand-side (electrical equivalent) geothermal solutions (geothermal heat pumps and direct uses of thermal waters) to displace electricity generation sources that emit lots of carbon dioxide.
- Work with the state Public Utility Commissions to ensure that utilities solicit geothermal power and offer PPAs that attract geothermal developers. These contracts should recognize all the unique values geothermal power can provide an electricity grid system, including ancillary service, firm and flexible power, reliability and reduction of line losses near the ends of the lines.
- Understand that geothermal is traditionally and most efficiently operated as base-load power (providing grid stability for states with intermittent renewables), but also can operate in flexible modes (for load following).

Valuing Geothermal Power

- When geothermal plants are intended to be operated in a flexible, load-following mode, contracts should be negotiated to include payment schedules that define the price of power in response to a dispatch signal transmitted by the independent system operator or other load-serving entity.
- To increase the ability of geothermal plants for frequency regulation (i.e., ramping generation assets up or down over a period of a few minutes), power pricing in future contracts should be negotiated to include payments specifically for frequency regulation services.
- When comparing geothermal power to other renewables during procurement, it's important to consider all the values of geothermal power, such as: ancillary services, geothermal's minimal integration cost, environmental attributes, and economic benefits that distinguish it from the intermittent renewables and from carbon emitting resources.



Geothermal Direct Use

Values and Benefits

Geothermal resources have been used directly, for their heat for centuries. The most famous examples might be the Roman bathhouses of Europe built throughout the Roman Empire. In modern direct-use systems, a well is drilled into a geothermal reservoir to provide a steady stream of hot water. The hot water is brought to the surface, and a mechanical system—piping, a heat exchanger, and controls—delivers the heat directly for its intended use. Projects can be scaled to any size, and can range from an individual home, to a single greenhouse or aquaculture pond, to a large district heating system.

Ball State Central GHP. *Photo courtesy of Geothermal Exchange Organization*

These applications decrease electricity demand by using an already hot and sustainable resource rather than converting electricity or fossil fuels into heat. The use of low- to moderate-temperature fluids, typically 38^{0}C (100^{0}F) to 150^{0}C (302^{0}F) are used for direct use projects. Approximately 85% of identified resources in the U.S. are below 93^{0}C. These resources are more likely to be located near potential users than traditional power resources since they are more widespread, often discovered during conventional water well drilling, and are designed with conventional off-the-shelf equipment.

The main uses of direct-use technology is industrial applications, agricultural drying, district heating, space heating, greenhouses, aquaculture, resorts and spas, snow melting, and cooling. Currently in the U.S. there are 19 geothermal district heating systems with several additional under construction, over 2000 individual heated buildings, 7 industrial and agricultural drying stations, 45 greenhouse complexes, 51 aquaculture operations, 242 resorts and spas, and 6 snow melting projects the use geothermal direct-use technology.[16]

Economics & Costs

Every geothermal direct-use project is unique and should be custom engineered. However, that does not add substantially to their cost. These systems are often not that complicated and can be built with off-the-shelf components and equipment commonly available. It is therefore hard

[16] (Toni Boyd, 2015)

to generally apply standard costs for all systems as can be done for electricity or fossil fuel systems. The economics of a project often depend on the user's needs, geothermal fluid temperatures and flow rates, price of the equivalent fossil fuel heating sources, and availability of government incentives. Generally, the larger the system needed, the higher the price will be for an alternative fossil fuel system for the same purpose. Furthermore, the better the quality of the geothermal resources nearby, the more economic these systems become.

Table 2: Typical Costs of Example Geothermal Direct-Use Systems by Type[17]

Application	Capital $/kW	Cost/year $/kWyr	O&M $/kWyr	Total $/kWyr	Typical Capacity Factor	Unit Cost cents/kWh
Residential Space Heating*	800	71.1	7.1	78.2	0.29	3.08
Space Heating*	500	44.4	4.4	48.8	0.25	2.23
District Heating	650	57.7	5.8	63.5	0.30	2.42
Greenhouse Heating	250	22.2	2.2	24.4	0.25	1.11
Aquaculture Pond Heating	200	17.8	1.8	19.6	0.69	0.32

Note: Based on 30-year life at 8.0% interest and O&M at 10% of capital cost. The above costs include a shallow well (<984 ft or 300 m) and no retrofit costs; however, cost can vary by as much as 100% depending on the local geology, hydrology, building construction, and infrastructure.
*Assumes one production and one injection well for a single building
**Heat pump figures are considered only for the heating mode and the capacity factor is a nation-wide average.

Case Studies

Klamath Basin Brewing Co.

The Klamath Basin Brewing Co utilizes a local geothermal district heating system in Klamath Falls, Oregon. On peak, the company uses about 1,700 therms of geothermal energy a month at a cost of $1,360. This system saves Klamath Basin Brewing about $1,190 a month during the on-peak season. During the off-peak season, the company saves about $300 a month, compared to generating the same heat with fossil fuels.[18]

Elko Nevada District Heating System

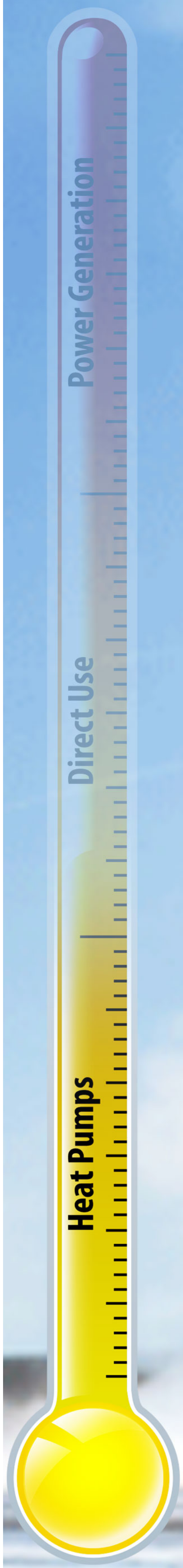
The system in Elko, Nevada, first began construction in 1982. It currently services 19 residential and commercial customers including a commercial laundry, a sewage treatment plant, and an industrial park. The system cost about $1.4 million. The customers are charged about $1.50 per 1000 gallons of water use pumped through the system. These charges equate to about 30% of the cost of natural gas.[19]

[17] (Lund, 2015)
[18] (Lund, 2015b)
[19] (Lund, 2015a)

Boise, Idaho Geothermal Heating District

Boise Public Works Department administers Boise's Geothermal Heating District. This system is the largest and oldest direct-use system in the U.S. Four independent heating districts supply energy-efficient heat to over 65 businesses in the downtown core area. The cost of extending the supply and return lines is about $50,000-$85,000 per city block in Boise.[20]

[20] (Neely, Galinato, & Johnson, 2006)



Geothermal Heat Pumps

Values and Benefits

According to the Department of Energy, buildings are the largest single sector of total U.S. energy consumption. The buildings sector accounted for over 40% of primary energy use in 2010 and consumes approximately one third more energy than either the industrial or transportation sectors.[21] Some 60% of the energy used in buildings is for "thermal loads." Thermal loads are the amount of energy needed to be added or removed from a space by the heating, ventilation and air conditioning (HVAC) system to keep the occupants comfortable. A third of that U.S. thermal load energy – over 3 quadrillion BTUs – is satisfied with electricity.

Given the high proportion of energy and electricity used by buildings in the U.S., Geothermal Heat Pumps (GHPs) offer a unique and highly efficient renewable energy technology for heating and cooling. GHPs use the natural insulating properties underground, the latent solar energy stored in the earth and, below 20 ft, geothermal energy to meet the thermal needs of a building through a process called "geothermal exchange." By drawing on this stored and ever-regenerating solar and geothermal energy the space conditioning requirements of a building can be met with a fraction of the energy normally required by conventional HVAC equipment. The earth is warmer in winter than is the air, and cooler than the air in summer.

Most GHPs work by circulating water in a closed system through a "loop field" of durable, high-density polyethylene pipe installed horizontally in the ground adjacent to or even vertically beneath a building. There are other types of GHP systems that use a loop field placed in water wells or a body of water to achieve the same geothermal exchange. Another example of a GHP is a "direct exchange" system, which uses a smaller loop field of copper pipe through which a refrigerant instead of water is circulated. All of these different types of GHP systems are similar in that they utilize the stable temperature of the earth to meet the heating and cooling needs of a building. In the winter, stored thermal energy is drawn out of the earth and used to meet the building's heating needs and in the summer, that process is reversed and building heat is rejected to the earth.

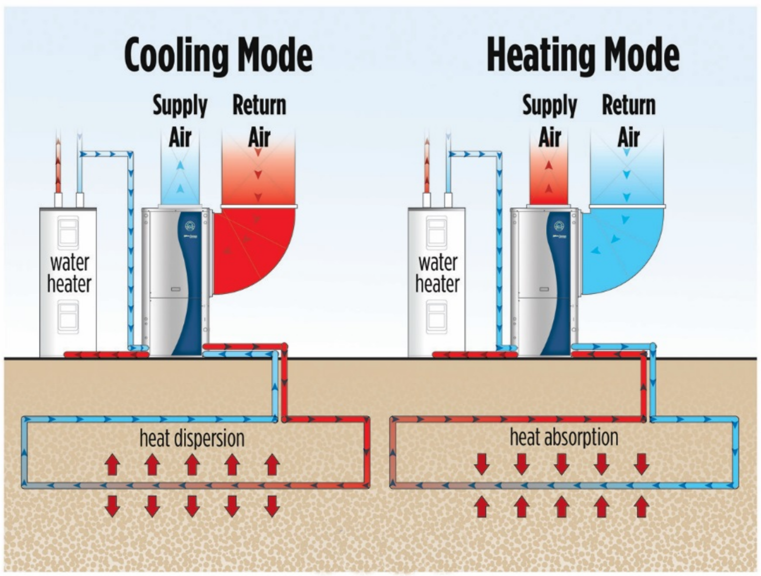
According to the U.S. Environmental Protection Agency (EPA), "Geothermal heat pumps are among the most efficient and comfortable heating and cooling technologies currently available . . . Energy Star-certified geothermal heat pumps are over 45 percent more energy efficient

[21] (U.S. Dept. of Energy, 2012)

than standard options."[22] And according to DOE, "The biggest benefit of GHPs is that they use 25% to 50% less electricity than conventional heating or cooling systems. This translates into a GHP using one unit of electricity to move three units of heat from the earth."[23]

By using the earth's free renewable thermal energy, GHPs can help lessen the load on electrical grids. This fact is especially true on hot summer days when consumer demand for air conditioning spikes and power generation resources are strained. GHPs flatten peak demand and reduce peak-load generation capacity that must be installed adding stability to the grid. Peak energy loads are the most expensive.

In addition to the effects on the electrical grid, GHPs significantly reduce carbon emissions. A 2010 study from Oak Ridge National Laboratory showed that aggressive retrofitting of all single-family homes across the country with GHPs would avoid the need to build up to 48% of new electric generation capacity projected nationwide by 2030.[24] Such a deployment of GHPs would save $38 billion annually on consumer utility bills and slash projected CO_2 emissions by 45%. The Oak Ridge study found that one ton (12,000 BTU/hr) of GHP capacity over a 20 year operating cycle avoids 21 metric tons of CO_2 emissions. The significant emissions reduction capability of GHPs makes them a technology type uniquely suited to meet the goals of states seeking policies to comply with EPA's 111(d) Clean power Plan.



Recommended New Geothermal State Policies & Practices

States have a number of options available for compliance with the EPA's 111(d) Clean Power Plan. GHPs are one of the most applicable technologies for compliance as they are a demand-side efficiency technology that can be deployed in all 50 states, and have a proven track record as the most efficient and renewable heating and cooling technology. The federal government recently recognized the thermal energy utilized by a GHP as a source of renewable energy and instructed government agencies to consider their use a method of meeting energy savings goals.

States wishing to incorporate GHP technology into their plan for CPP compliance should adopt the following recommendations:

[22] (Energy Star, 2015)
[23] (US Dept. of Energy, 2015)
[24] (Xiaobing Liu, 2010)

- Amend state Renewable Energy Portfolio Standards to recognize the renewable thermal energy produced by GHPs and create programs to measure and calculate the aggregate of this renewable energy for all commercial and residential installations. In states where GHPs are not included in the Energy Efficiency Portfolio Standard, the standard should be amended to include GHPs. By adding GHPs to these standards, states are able to more easily meet theirs RPS goals as well as CPP targets.
- Recognize the unique ability of GHPs to significantly lower electric utility peak demand. By deriving the bulk of the required thermal energy for heating from the latent solar and geothermal energy stored in the earth, GHPs reduce the burden on power generation facilities. And in the cooling mode, GHPs reject a building's heat to the ground instead of outside air, cutting consumption and decreasing demand on strained generation facilities. One recent DOE study showed that a home with a GHP system gets 75% of its heating energy from the earth.
- Recognize the carbon emissions reduction attributable to GHPs. The DOE has performed studies that verify the unique ability of GHP technology to reduce greenhouse gas emissions. Widespread GHP adoption can dramatically diminish the level of carbon released into the atmosphere.
- Encourage public utilities to support GHP deployment through on-bill financing programs, special rate designs, and homeowner rebates. With focused incentives, utilities are able to deliver real and lasting savings to homeowners and businesses while meeting their own demand reduction targets.
- Recognize the large percentage of energy that is devoted to HVAC applications and seek to implement the most efficient/renewable solutions available.

Geothermal Heat Pump Costs

Geothermal heating system prices can vary depending on the type of ground heat exchanger (usually vertical or horizontal), geographic location and on-site geological conditions. On average, a typical home of 2000 square feet will require 4 tons of heating and cooling capacity with an average system installation cost between $5,000 and $7,500 per ton.

Another way to express cost would be by the type of heat pump system installed. Geothermal heat pump costs for a 4-ton unit:

- Closed loop water to water = $34,000 ($8,500/ton)
- Open loop water to water = $28,000 ($7,000/ton)
- Closed loop water to air = $28,800 ($7,200/ton)
- Open loop water to air = $22,000 ($5,500/ton)
- Direct geoexchange = $16,000 ($4,000/ton)

These are average numbers and will vary depending upon local drilling or excavation costs. Water to water GHP installation costs include radiant flooring. Closed loop water to air is the most frequent type of installation (cost shown includes duct work). Open loop water to air is a typical "pump and dump" system. Direct geoexchange uses copper pipe underground, but excavation/drilling costs are lower.

In general four factors determine the cost of a heat pump installation in a home or commercial building.[25]

1. **Size of the Home/Building** – The larger the area covered, the more heating and cooling the building will demand.
2. **Size of the Heat Pump** - Based on the size of the home, insulation, and climate the amount of heating and cooling needed is calculated, which in turn enables a contractor to calculate the size of the heat pump.
3. **Size of the Loop Field** - The size of the system (3-ton, 4-ton, etc.) along with the local climate will dictate the amount of pipe that needs to be inserted into the earth.
4. **Usability of Current Ductwork** - In most cases, existing ductwork requires little to no adjustment to be suitable for geothermal heating and cooling. However, if existing ductwork is not in place, than the homeowner or business owner will need to incur the full expense of installing it.

Case Studies

IKEA in Kansas City & Denver Area

IKEA globally by January 2015, installed more than 300,000 solar panels, owns/operates approximately 137 wind turbines in Europe, and has geothermal systems at approximately 50 locations. At the Denver location in Centennial, Colorado, IKEA drilled 130 boreholes to a depth of 500 feet. The central plant includes ten, 35-ton water-water heat pumps that drive a variable air volume system for most of store and nine 1,500 gallon ice storage tanks. At the Kansas City location in Merriam, Kansas, 180 boreholes were drilled to a depth of 600 fet. The system in Kansas City is the building's primary source of heating and cooling. These two systems are a great demonstration of the economic viability of installing and operating geothermal heat pump systems on a large commercial scale, in two very different states, instead of using fossil fuels for the same purpose.

[25] (Geothermal Genius, 2015)

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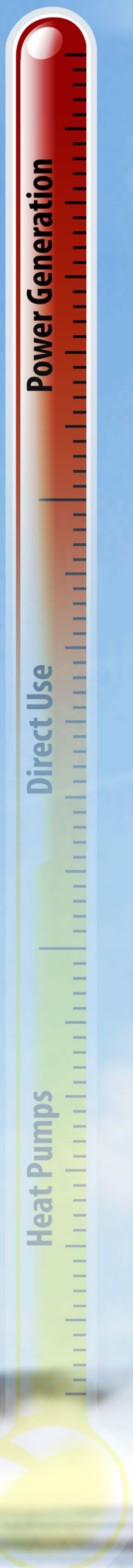


Illustrations of Geothermal Power Technology Types

Figure 1: Dry Steam Power Plant Configuration[26]

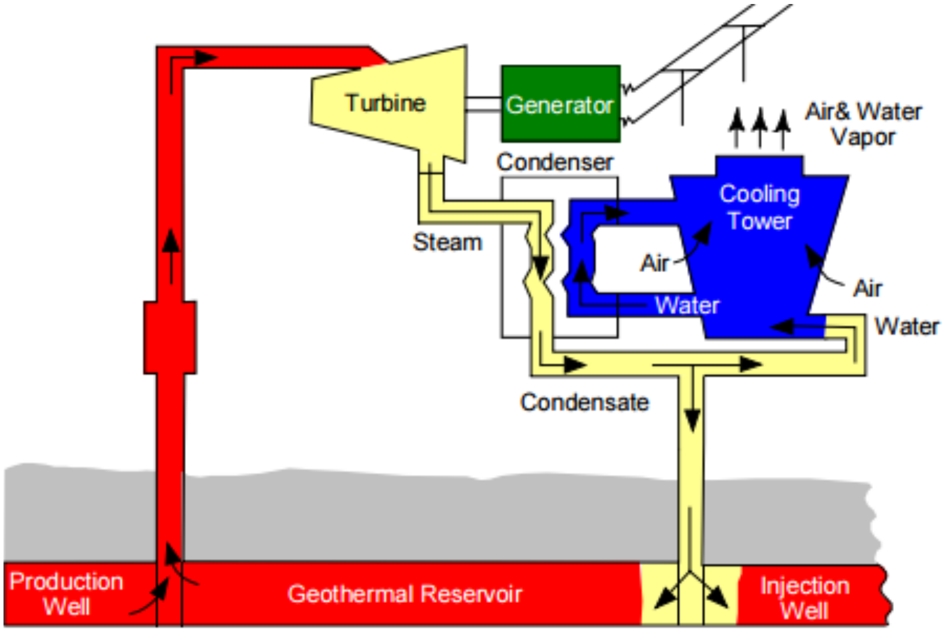
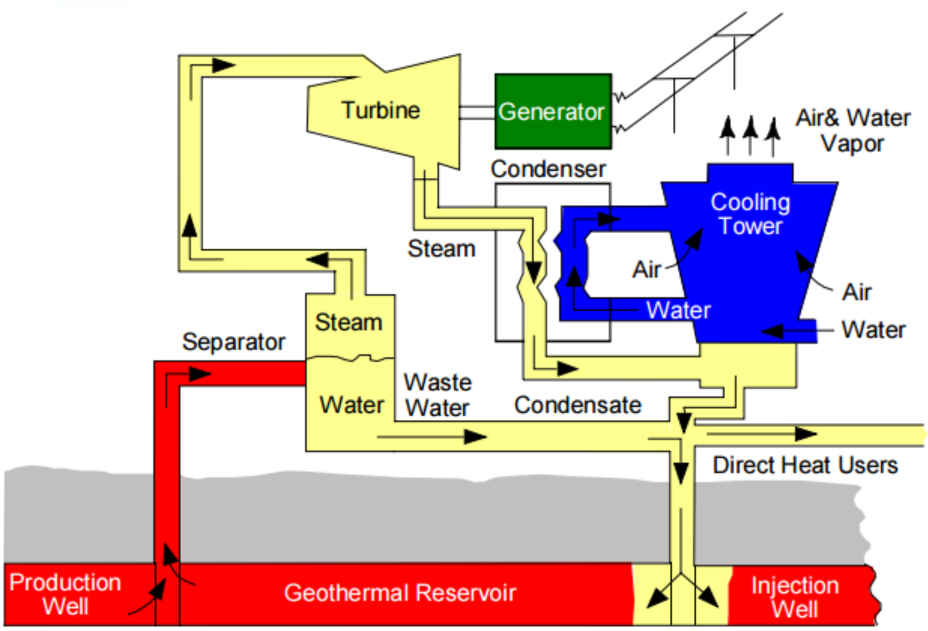
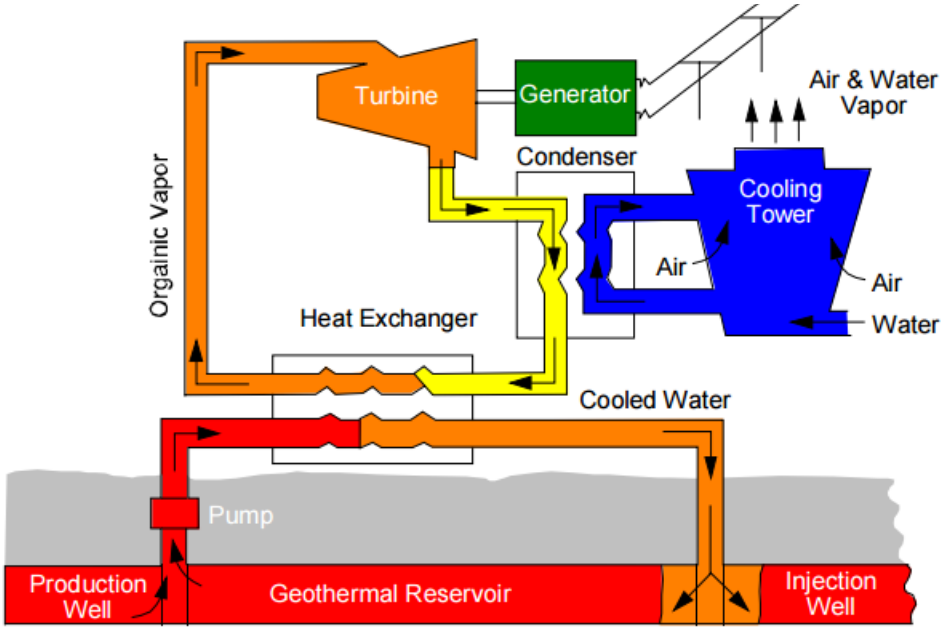


Figure 2: Single Flash Steam Configuration[27]



[26] (Kagel, 2008)
[27] *Ibid.*

Figure 3: Binary Power Plant Configuration[28]



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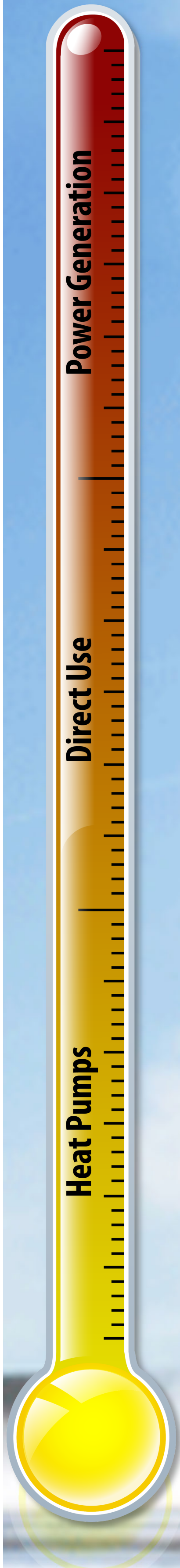
[28] *Ibid.*

Appendix B



State-Specific Geothermal Potential

Factsheet Sources: Electricity and Direct Use

(Energy Information Administration, 2015c)
(Williams, Reed, Mariner, DeAngelo, & Galanis, 2008)
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(Meldrum, Nettles-Anderson, Heath, & Macknick, 2013) – For lifecycle water charts in applicable states

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(Energy Information Administration, 2015c)
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