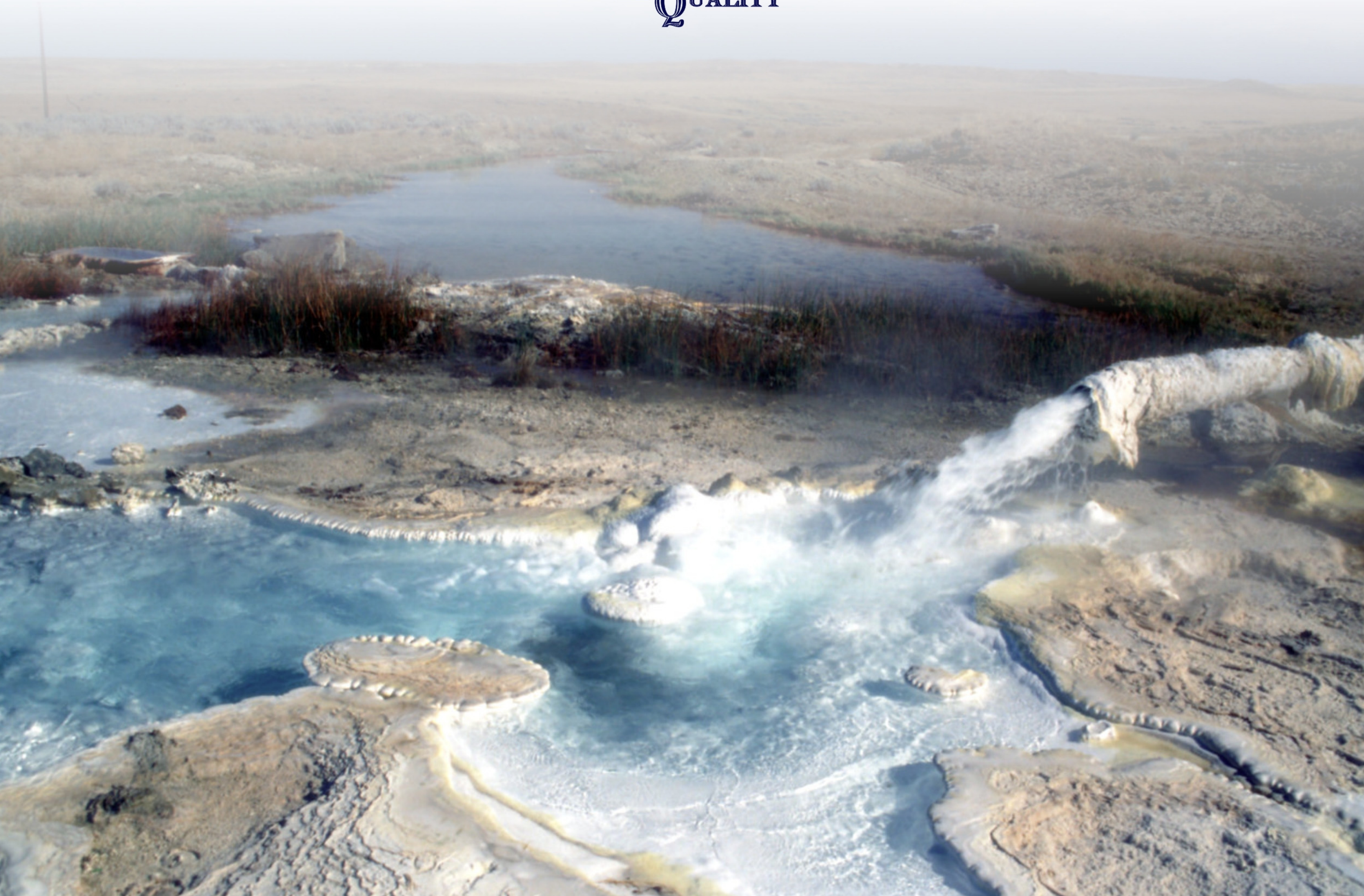
Geothermal Energy in Montana

A Consumer's Guide

By Jeff Birkby

Montana Department of Environmental Quality



Hunters Hot Springs Hotel, east of Livingston, Montana

By Jeff Birkby

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Cover Photo by Jeff Birkby
A hot water well located near the town of Angela, north of Miles City in eastern Montana, produces 185 degree F water.
Inside back cover and all historic postcard images appear courtesy of the author from his personal collection.

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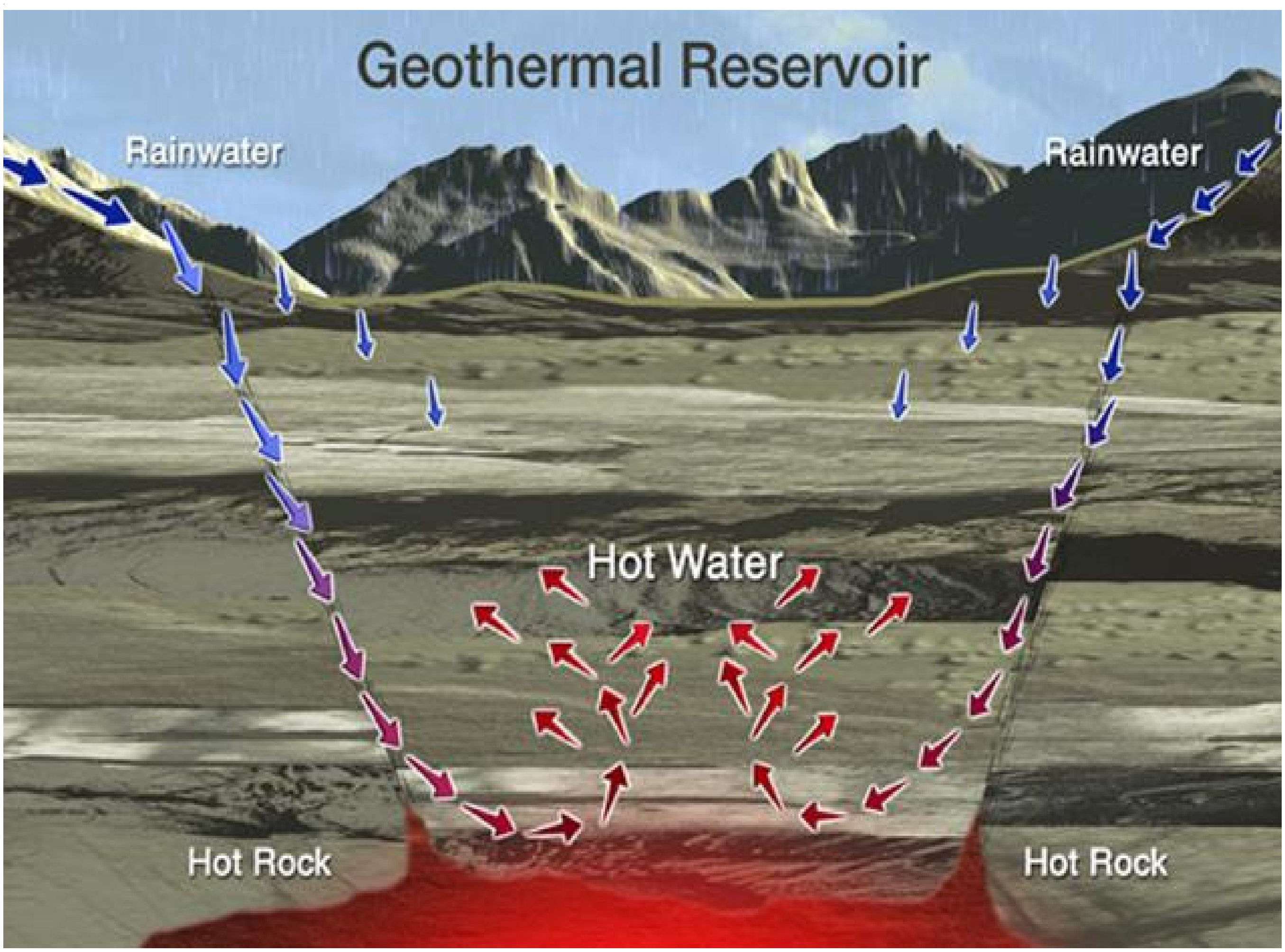
1. What is Geothermal Energy?

Geothermal energy is the natural heat of the earth. The earth's core consists of molten rock, called magma, which can be as hot as 7,000 degrees F. The immense heat of the earth cools as it approaches the surface.

The top mile or so of the earth's crust has a fairly constant temperature gradient of about 1 degree F for every 100 feet of depth. This means that the temperature 1,000 feet below the surface of Montana is usually around 10 degrees hotter than the ground just beneath our feet. Temperatures at a depth of 10,000 feet are normally around 100 degrees warmer than the surface.

This natural heat gradient is present throughout the world. However, in many spots on the earth (including Montana), we have much hotter areas of rock, sometimes caused by shallower deposits of magma that rise to within a few miles of the earth's surface. Yellowstone National Park's thousands of hot springs and geysers are thought to occur because of the presence of a shallow magmatic "hot spot."

To transfer this geothermal heat of the earth to the surface, a second element is needed — water. Deep aquifers of water may pass through rock layers heated by shallow magma. Water may also percolate down through vertical cracks in the rock, known as "faults," where the water is then heated. This hot water may then find other faults leading back to the surface, where it can emerge as a hot springs.



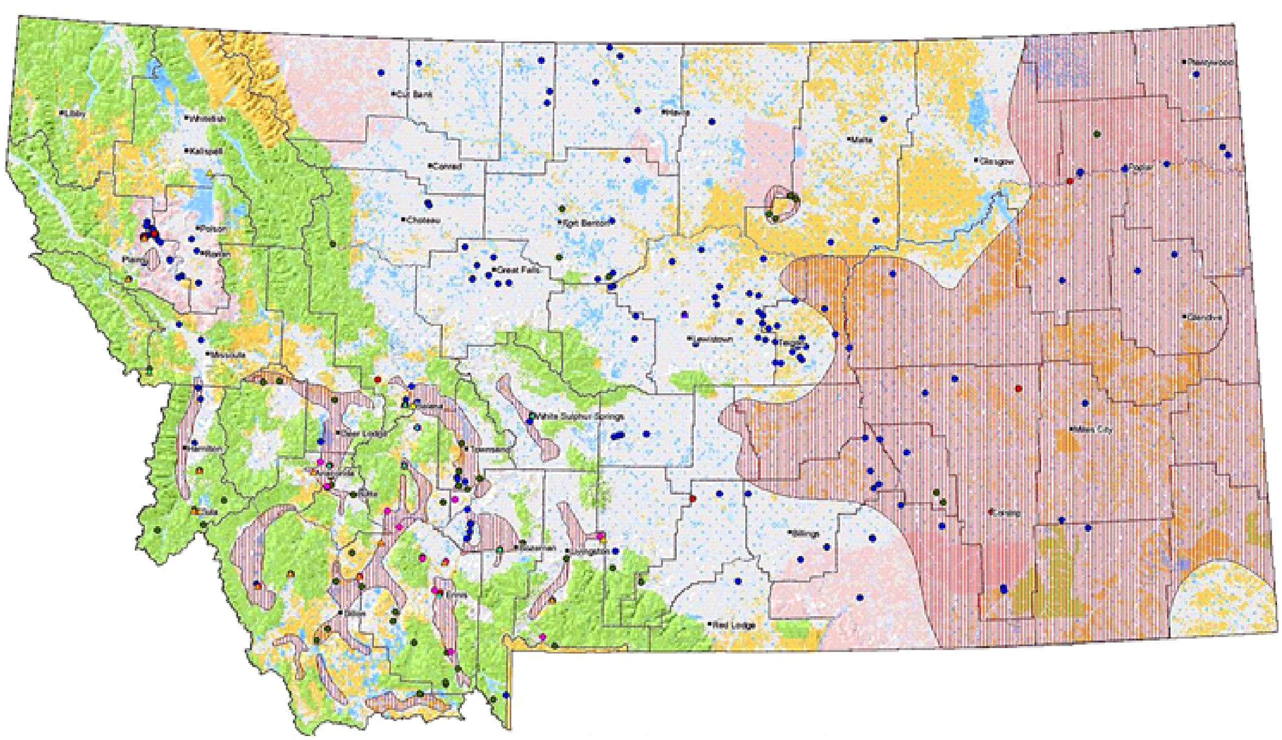
Geothermal reservoirs or hot springs develop when rainwater or deep aquifers are warmed by hot rocks heated below by magma. *© 2000 Geothermal Education Office*

2. Where is Geothermal Energy Found in Montana?

Montana is one of 14 western states that have natural hot springs and hot water wells. In the western third of Montana, hot springs are usually located on the edges of mountain valleys. Rainwater finds its way down geologic faults on the sides of the valleys, where it circulates at great depth. The heated water then emerges along other faults as hot springs. There are a few hot springs in western Montana that occur higher in mountain ranges, but the majority of Montana's hot springs follow this pattern of emerging along the edges of valleys in the mountainous western portion of the state. The hottest natural hot springs in Montana, located just north of the town of Ennis, has been measured at 180 degrees F. But most of the hot springs in western Montana are in the range of 85 degrees to 140 degrees F.

Eastern Montana has a different geothermal pattern. There are few natural hot springs visible on the surface in the far eastern portion of the state. Instead of fault systems that allow water to circulate at depths, eastern Montana is underlain by a very deep layer of limestone called the Madison Formation. This porous rock is located at depths of 8,000 feet or more. The rock layer acts like a sponge, with tiny pores filled with water. The sheer depth of this rock layer in the earth causes the water to heat up to temperatures that in some cases exceed boiling — more than 250 degrees F in some areas near the town of Poplar in northeast Montana.

Montana Geothermal Resources



Map of Montana's Geothermal Resources. The dots on the map represent hot water wells and hot springs. Shaded and crosshatched portions represent areas of high potential for geothermal resources.

Image credit: http://geothermal.inel.gov/maps/mt.jpg

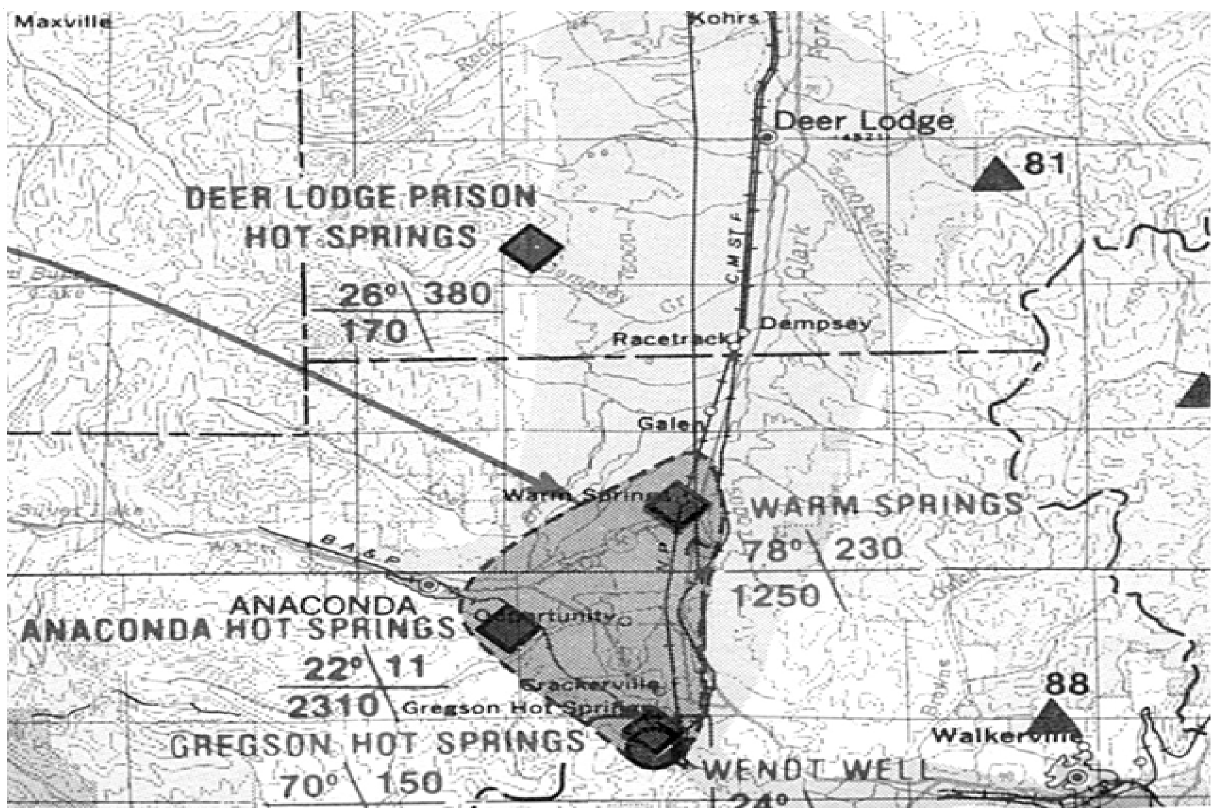
2. Where is Geothermal Energy Found in Montana? – *continued*

In several locations in central and eastern Montana, well drillers in the early 1900s struck this hot water by accident. Sometimes the hot water wells were left to flow onto the open prairie, such as a hot water well near Jordan, while in other cases such as Sleeping Buffalo resort near Malta, a well was converted for use in a hot springs resort. In the oil and gas fields in eastern Montana, oil wells often co-produce hot water at temperatures above boiling point.

The Montana Department of Environmental Quality (DEQ) has developed an online database of locations where geothermal resources have been identified. (The DEQ geothermal resource information, including the database, is available on the following website: www.deq.mt.gov/Energy/geothermal/default.mcpx. The DEQ geothermal database for Montana shows at least 15 high-temperature sites, a few of them with estimated deep-reservoir temperatures exceeding 350 degrees F. Among these 15 sites are locations in the vicinity of Helena, Bozeman, Ennis, Butte, Boulder, and White Sulphur Springs.

Another state agency investigating the state's geothermal resources is the Montana Bureau of Mines and Geology in Butte. The bureau has gathered temperature, depth, flow rates, and water chemistry for nearly 300 warm wells and springs throughout Montana. The bureau is currently updating and compiling a new geothermal database for Montana as part of a national geothermal database funded by the U.S. Department of Energy. Visit the Bureau of Mines and Geology geothermal website:

http://mbmggwic.mtech.edu/sqlserver/v11/menus/menuProject.asp?mygroup=GEOTHERM&



A section of the Montana Geothermal Resources map produced by the Montana Bureau of Mines and Geology. Shown above are temperature and flow rate information for hot springs in the Deer Lodge Valley, east of the town of Anaconda.

Sonderegger, J.L., Bergantino, R.N., 1981,
Geothermal Resources Map of Montana,
Montana Bureau of Mines and Geology: Hydrogeologic Map 4

3. History of Geothermal Energy Use in Montana

Native Americans in Montana often wintered near hot springs, believing in the healing benefits of the warm mineral water. Early pioneers from the eastern United States who passed by hot springs in Montana recorded seeing tribal teepees nearby. In 1864, Dr. A.J. Hunter reported more than 1,000 teepees clustered around a hot springs near present-day Big Timber, and noted that many tribal members were bathing in the mineral water. Dr. Hunter later filed a claim on this hot springs and built a popular resort there that flourished into the 1930s.

The first white men to visit Montana's geothermal resources were probably the explorers Lewis and Clark, who camped near Lolo Hot Springs and boiled meat in Jackson Hot Springs in 1805 and 1806. Early trappers, miners, and explorers sought out Montana hot springs to take a hot bath and wash their clothes. Soaking in primitive hot springs pools in Montana is still as popular now as it was 150 years ago with the early settlers.

Early day soakers at Camas Hot Springs in western Montana.
University of Montana archives

3. History of Geothermal Energy Use in Montana – *continued*

During Montana's gold rush years in the 1860s to the early 1880s, crude hot springs bathhouses and guest cabins were built near many of Montana's geothermal resources in the western part of the state. Bathhouses built near the towns of Emigrant, Virginia City, Boulder, Clancy, and Helena all served as gathering places for gold prospectors, while cast-iron tubs in a log cabin offered cowboys a bath at a hot water well drilled in eastern Montana in the 1930s.

Cast iron tub filled with steaming water at Angela Flowing Well in eastern Montana, circa 1970.

Photo by Terri Stewart

3. History of Geothermal Energy Use in Montana – *continued*

With the coming of the railroad to Montana and more urban development, a new level of luxury replaced many of the early hot springs accommodations. The thirty-year period from the 1890s to the 1920s brought major luxury hot springs resorts to Montana, including Hunter's Hot Springs, Chico Hot Springs, Corwin Hot Springs, Boulder Hot Springs, and the most elegant of all, the Broadwater Natatorium and Hotel near Helena.

Exterior of Broadwater Natatorium near Helena, circa 1889.

3. History of Geothermal Energy Use in Montana – *continued*

Prohibition, fires, an earthquake, and lack of sufficient revenue led to the destruction and closure of several of these magnificent spas, and those hot springs resorts remaining in Montana saw a decrease in visitors from the 1940s through the 1970s. But many of Montana's hot springs have seen a resurgence in the past 20 years as visitors rediscover the pleasure of soaking in Montana's soothing hot water.

Present day soakers enjoying a hot springs as it mixes with cooler river water in Yellowstone National Park just south of Gardiner, Montana.

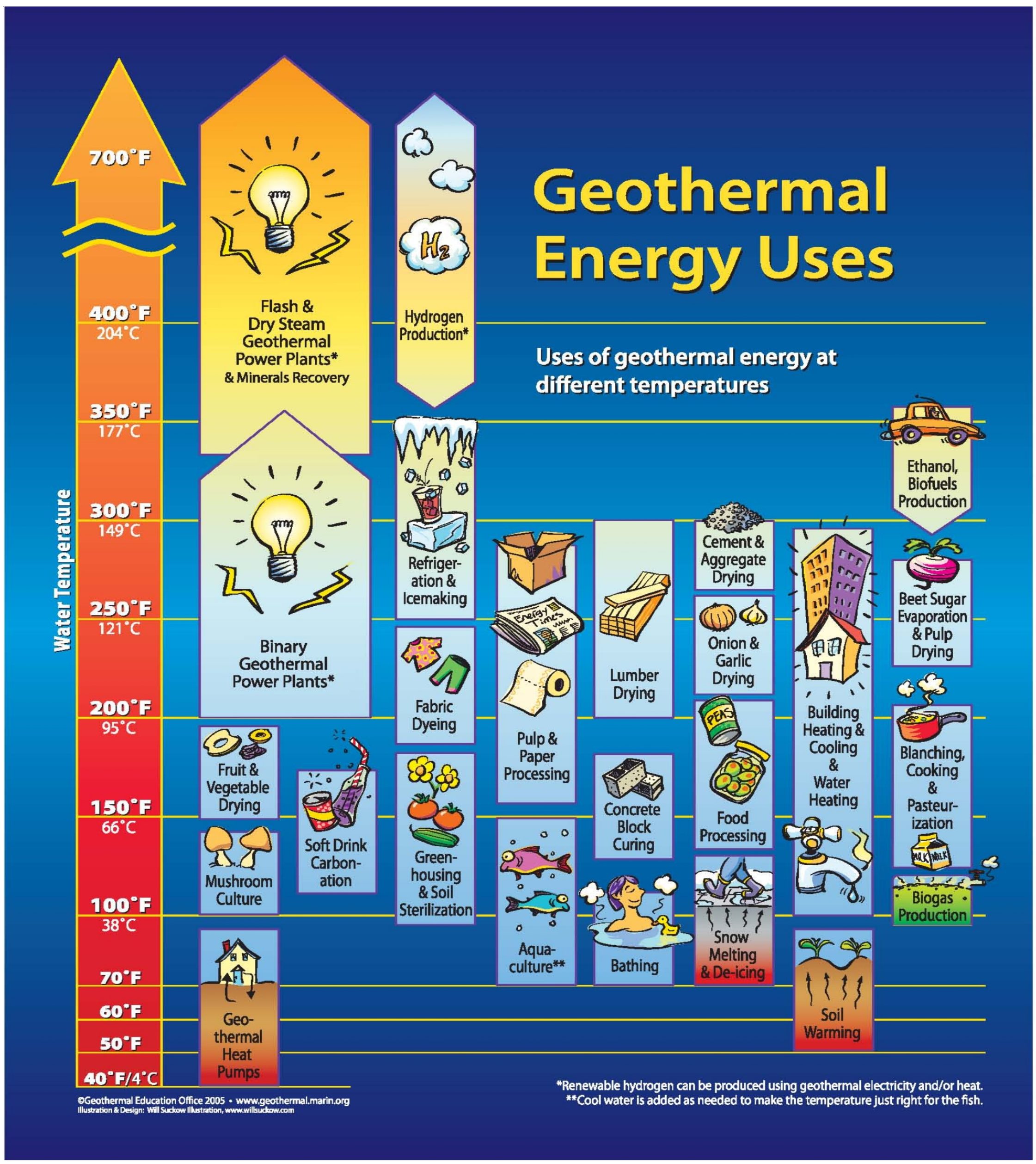
Photo by Jeff Birkby

4. Geothermal Energy Uses — An Overview

Geothermal energy is used in a wide variety of applications, depending on the temperature of the resource. Cooler geothermal water (and even "cold" ground water) is used in ground water "heat pumps," which take the energy from the water to heat a secondary fluid to a vapor, which can then be compressed to give off heat.

At slightly warmer temperatures (between 70 and 100 degrees F), geothermal energy is primarily used for aquaculture and soil warming in agriculture. Between 100 and 200 degrees F the range of geothermal uses expands, including space heating, dehydration of agricultural products, and water heating. Electrical generation from geothermal power can begin at around 170 degrees F, when a binary fluid is boiled with the geothermal water to create steam to run a turbine.

The graphic below illustrates the range of geothermal uses possible at different temperatures.



© Geothermal Education Office, 2005

5. Geothermal Heat Pumps

Geothermal heat pumps, also known as ground source or ground water heat pumps, are a highly efficient renewable energy technology. Geothermal heat pumps are used for space heating and cooling, as well as water heating. The greatest advantage is that they work by concentrating naturally existing heat, rather than producing heat through combustion of fossil fuels. For cooling, the reverse process occurs.

The biggest benefit of geothermal heat pumps is that they use 25 to 50 percent less electricity than conventional heating or cooling systems. This translates into a geothermal heat pump using one unit of electricity to move three units of heat from the earth or from geothermal water. According to EPA, geothermal heat pumps can reduce energy consumption up to 44 percent compared to air-source heat pumps and up to 72 percent compared to electric resistance heating with standard air conditioning equipment.

Types of Geothermal Heat Pumps

Geothermal heat pumps are either closed or open loops. The three types of closed-loop system installations include horizontal, vertical, and pond/lake. The fourth type of ground source heat pump is the open-loop system. To determine which option is the best, you must look at the climate, soil conditions, available land, and local installation costs at your site. All of these types of systems can be used for residential and commercial building applications.

Closed-Loop System – Horizontal

Horizontal ground source heat pump installation is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available. It requires trenches at least four feet deep. The most common layouts either use two pipes, one buried at six feet, and the other at four feet, or two pipes placed side-by-side at five feet in the ground in a two-foot wide trench. The method of looping pipe allows more pipe in a shorter trench, which cuts down on installation costs and makes horizontal installation possible in areas it would not be with conventional horizontal applications.

Closed-Loop System – Vertical

Vertical systems are often used for large commercial buildings and schools because the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching, and they minimize the disturbance to existing landscaping. For a vertical system, holes approximately four inches in diameter are drilled about 20 feet apart and 100 to 400 feet deep. Into these holes go two pipes that are connected at the bottom with a U-bend to form a loop. The vertical loops are connected with horizontal pipe, placed in trenches, and connected to the heat pump in the building.

Closed-Loop System – Pond/Lake

If your site has an adequate water body, this may be the lowest cost option. A supply line pipe is run underground from the building to the water and coiled into circles at least eight feet under the surface to prevent freezing. The coils should only be placed in a water source that meets minimum volume, depth, and quality criteria.

5. Geothermal Heat Pumps – *continued*

Open-Loop System

An open-loop system uses a well or surface water body such as a pond or lake as the heat exchange fluid that circulates directly through the ground source heat pump system. Once the water has circulated through the system, it returns to the ground through the well, a recharge well, or surface discharge. This option is only practical where there is an adequate supply of relatively clean water, and all regulations regarding ground water discharge are met.

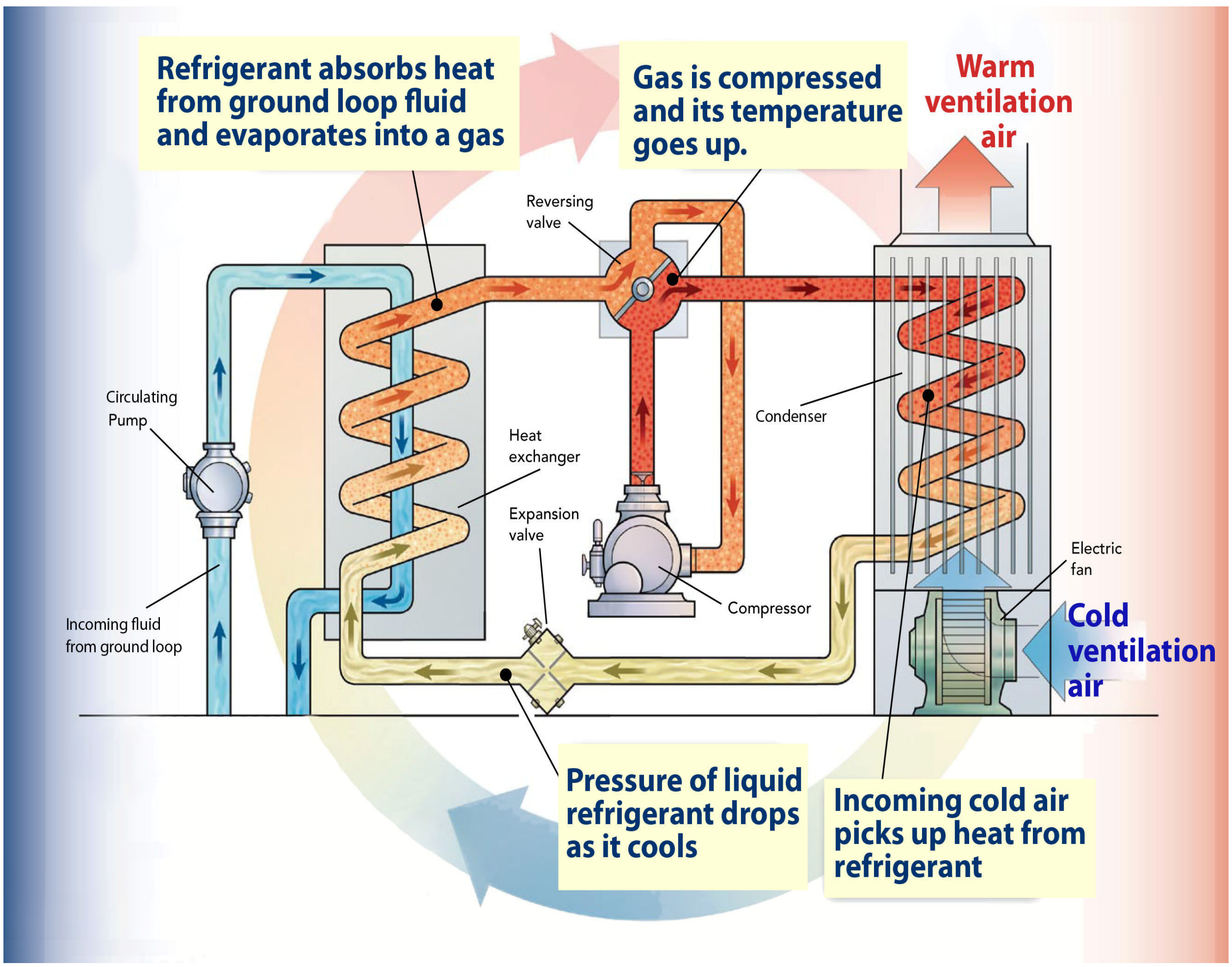


Illustration modified from Fine Homebuilding.

Source: Cold Climate Housing Research Center

5. Geothermal Heat Pumps – *continued*

Permitting Information for Geothermal Heat Pumps

The three permitting agencies involved in geothermal heat pump regulation in Montana are the U.S. Environmental Protection Agency (EPA), the Montana Department of Natural Resources and Conservation (DNRC), and the Montana Department of Environmental Quality (DEQ).

The EPA only regulates open-loop ground source heat pumps. As the applicant, you must submit information on your proposed open-loop ground source heat pump by completing the "Site Information Request Fact Sheet – Geothermal Injection Well" located at http://www.epa.gov/region8/water/uic/FSGeo.pdf.

Single family residential homes are excluded from this EPA permitting requirement.

If it is determined that your proposed heat pump system does not need a permit, the system will be "rule authorized" and there are no further actions that you must take.

The Montana DNRC requires a Water Right Permit for ground water use (originating after June 30, 1973) over 35 gallons per minute (gpm) or 10 acre-feet per year or any surface water appropriation. A Ground Water Certificate is required for developed ground water use (originating after June 30, 1973) under 35 gpm, not to exceed 10 acre-feet per year.

The Montana DEQ requires a Montana Ground Water Pollution Control System permit if the water used for a ground source heat pump is altered (e.g., additives to the water) and discharged back into the aquifer. If the water is not altered no permit is necessary. Temperature changes typically do not trigger a permit requirement. Contact the Permitting and Compliance Division at (406) 444-3080 to discuss a specific project or for additional information.

6. Aquaculture

Aquaculture is the production and sale of aquatic plants and animals in confined ponds or raceways. Geothermal aquaculture uses naturally occurring warm water to accelerate the growth of fish, shellfish, reptiles, amphibians, and aquatic plants. Aquaculture is a high potential development area for low-temperature geothermal resources, including areas in Montana. Geothermal aquaculture facility owners in the United States grow alligators, bass, catfish, giant fresh water prawns, goldfish, koi, lobster, snails, sturgeon, tilapia, tropical fish, trout, turtles, and water lilies. There are currently at least four dozen geothermal aquaculture operations in 11 western states. Rearing fish in controlled year-round temperatures can boost growth rates by 50 to 100 percent, dramatically increasing the number of harvests possible each year.

The use of geothermal water for aquaculture depends on the water temperature and the water chemistry. Some geothermal water in Montana, including the very salty hot brines that emerge from the oil wells in the eastern part of the state, contains minerals that make it unsuitable for direct use in aquaculture. However, geothermal water that is too toxic for direct use in aquaculture can be run through a heat exchanger, where the hot water transfers its heat to more potable water that can then be used in aquaculture facilities. Aquaculture usually needs a constant water temperature of 60 to 90 degrees F, depending on the species, so many of Montana's geothermal resources are hot enough for this purpose. Water quality and flow availability may be limiting factors to aquaculture operations.

Although Montana has little experience with aquaculture facilities, aquaculture is big business in neighboring Idaho. Over a dozen geothermal aquaculture facilities are currently operating in Idaho, with continued growth expected.

Tilapia are often raised in geothermal aquaculture operations in the western United States.

Source: NREL Photographic Exchange

6. Aquaculture – *continued*

Alligators are raised in ponds heated with geothermal energy in Colorado.

Source: NREL Photographic Exchange

7. Greenhouse Heating

Greenhouse heating is one of the most common uses of geothermal resources. Because of the significant heating requirements of greenhouses and their ability to use low-temperature fluids, they are a natural application in Montana. A wide variety of plants are grown in geothermal greenhouses, including roses, tomatoes, lettuce, cucumbers, and other vegetables; tree seedlings; poinsettias; potted plants; and bedding plants.

Flowers and bedding plants are popular choices for geothermal greenhouse production.

Photo by Jeff Birkby

Most greenhouse operators estimate that using geothermal resources instead of traditional energy sources saves about 80 percent of fuel costs — but keep in mind this is only about 5 to 8 percent of total operating costs for a greenhouse business. The relatively rural location of most geothermal resources in Montana also offers advantages for geothermal greenhouse operations, including clean air, lower labor costs compared to big cities, and lower land costs. However, the distance to markets can be a big barrier to greenhouse operations in Montana, no matter whether they are heated with geothermal energy or fossil fuels.

The growing interest in local food production had helped open up new opportunities for Montana greenhouse operations. A geothermal greenhouse near Silver Star in southwestern Montana has been producing tomatoes year-round for more than a decade, and has found a market niche selling those tomatoes at local farmers' markets and restaurants in Bozeman and Butte.

In late 2011 a community organization in Ennis completed the construction of two large greenhouses that will use water from a 190 degree F hot springs to provide year-round heating for growing vegetables for the local market. And Chico Hot Springs Resort, just north of Yellowstone National Park, has had a geothermally heated greenhouse in operation for several years. The fresh herbs, flowers, and vegetables grown in this greenhouse are featured in many of the menu items in Chico's gourmet restaurant.

7. Greenhouse Heating – *continued*

A banana tree grows year-round in the geothermally heated greenhouse at Chico Hot Springs Resort north of Yellowstone National Park.

Photo by Jeff Birkby

Geothermal Greenhouse Feasibility Checklist

- ✓ **What plants do I want to grow? (Tomatoes, herbs, cut flowers, other vegetables are most common.)**
- ✓ **How much can I produce in my geothermal greenhouse, given my local climate, available daylight, and the greenhouse temperature I can maintain with the geothermal heating system?**
- ✓ **Do I have experience growing greenhouse crops? Who will I rely on for growing expertise?**
- ✓ **Do I have the business and marketing skills to run a greenhouse operation? Can I learn them or hire experts?**
- ✓ **What is the market for my product? Do I have a special market niche (organic, low-spray, specialty crops, local)? How far away is the market? Is it a local Montana market? Is it seasonal? Year-round?**
- ✓ **Who is my competition? What makes my product different, better, unique?**
- ✓ **How much will I be paid for my product? How much are others with similar products paid? Do I need to guarantee delivery of a certain amount of product?**
- ✓ **How much will it cost to produce this product? Do I clearly understand the total costs of running a greenhouse operation?**
- ✓ **Finally, given the costs, resources, market, and projected sales, will I make enough money to make a profit?**

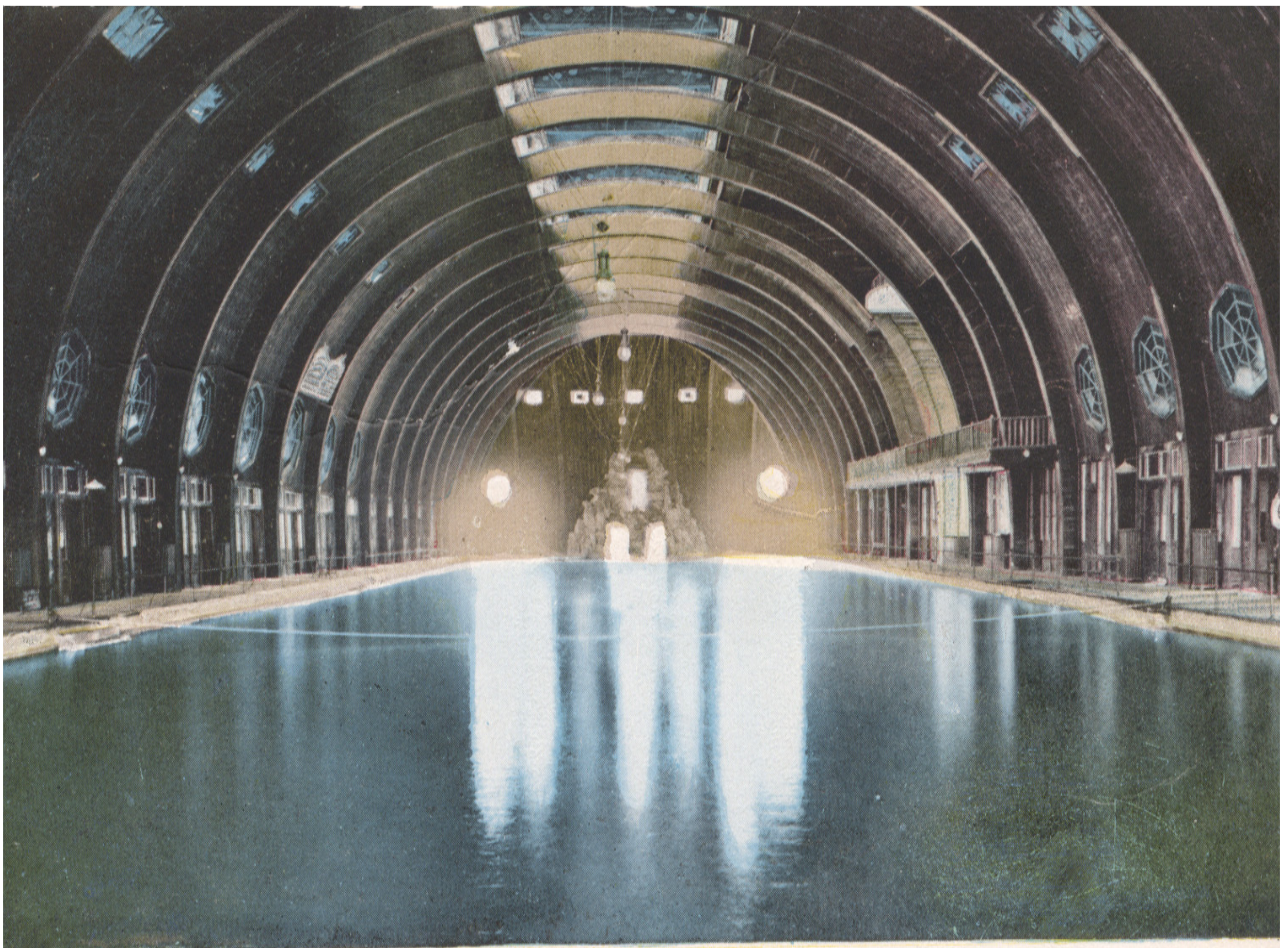
(Adapted from *Geothermal Greenhouse Information Package,* Tonya Boyd, Oregon Institute of Technology, 2008)

Exterior view of geothermally heated greenhouse at Chico Hot Springs Resort, a few miles north of Yellowstone National Park.

Photo by Jeff Birkby

8. Swimming Pool Heating

The earliest use of geothermal energy in Montana was most likely for bathing, soaking, and swimming. While these pioneer hot springs pools were often undeveloped or simply enclosed by crude cabins, Montanans began constructing more elaborate spas and pools in the 1880s. Several of these elegant pool structures, such as the Broadwater Natatorium near Helena and the Hunter's Hot Springs plunge near Big Timber, were some of the largest buildings built in Montana at the time.



Interior of the Broadwater Natatorium near Helena, Montana circa 1889.

Today more than 200 hot springs resorts and spas in the western United States use geothermal energy in their swimming pools, including at least a dozen swimming pools in Montana.

Ensuring Water Quality for Montana's Hot Springs Soakers

Montana health regulations were proposed in the 1990's to require chlorination of all hot springs swimming pools, similar to what is done in municipal swimming pools. Since many bathers visit hot springs resorts specifically to soak in the natural hot water, the chlorination requirement was opposed by resort owners.

Owners of Montana hot springs resorts created the Montana Mineral Hot Springs Association in 1994 to address this chlorination issue. In 1995 the association helped pass a bill in the Montana Legislature that clarified water quality issues for Montana hot springs resorts. All natural hot springs pools at resorts may now operate without chlorinating their water, provided all of the hot water is exchanged in the pool at least once every eight hours, and the pools are drained and cleaned every 72 hours. This helped ensure the safety of all soakers while avoiding chlorination of the hot springs water. Temperature and pH in the soaking pools must also be carefully monitored.

Outdoor pool at Quinn's Hot Springs Resort in Western Montana.

Photo by Jeff Birkby

Ensuring Water Quality for Montana Hot Springs Soakers – *continued*

Outdoor pool at Fairmont Hot Springs Resort near Butte, Montana.

Indoor pool at Bozeman Hot Springs. Small hot and cold soaking pools are located at the right end of the large swimming pool.

Photos by Jeff Birkby

9. Space Heating of Buildings

Several resorts and residential structures in Montana use geothermal energy for space heating. Hot springs or wells provide most, if not all, of the heating needs for these buildings, even in the coldest of Montana winters.

Almost all of the hot springs resorts in Montana use geothermal water not only to provide heat to their soaking and swimming pools, but also to provide space heating for their hotels and hot water for their laundry needs.

Space heating of an individual building with geothermal energy in Montana usually makes economic sense, provided there is a suitable geothermal resource close enough at hand.

A variety of methods are used to transfer the heat from the geothermal fluid to heat the air in a building. The most common type of space heating system used in a conventional home is a forced air heating system.

Adapting an existing forced air system to use geothermal heat, or designing a system for new construction, is a straightforward process. A finned coil (similar to a car radiator) is placed in the supply air duct, as well as a motorized valve to control the geothermal water flow in response to a signal from a thermostat. Pipes then deliver the geothermal water to and from the coil.

Other methods of space heating with geothermal water include piping the hot water through a radiant slab in the floor of a building. The Hillbrook Nursing Home located near the old Alhambra Hot Springs south of Helena uses the hot springs water for radiant heating. Pipe was laid a few inches beneath the floor surface in the concrete floor of the nursing home as it was poured. The geothermal water then flows through the pipes, warming the concrete which then heats the air in the living space above.

Domestic hot water heating often requires higher temperature water than space heating. This is because heat is being transferred to heat water to 110º F or greater rather than warming air to 70º F in a space heating application. The laundry water at Warm Spring State Hospital northwest of Butte is preheated with geothermal water, saving a considerable amount of state tax dollars that would otherwise have been spent on fossil fuel.

Major resorts in Montana using geothermal energy to heat their buildings include Boulder Hot Springs Inn and Spa, Bozeman Hot Springs, Chico Hot Springs Resort and Day Spa, Fairmont Hot Springs Resort, the Symes Hotel in the town of Hot Springs, and the Spa Hot Springs Motel and Clinic in White Sulphur Springs. Individual homes near hot springs also are heated with geothermal energy, including homes in Helena and the Bitterroot Valley north of Hamilton.

Chico Hot Springs Resort in Southwest Montana uses geothermal energy to heat its convention center.

Photo by Jeff Birkby

10. District Heating

District heating systems have been in use in Montana since the turn of the previous century. Even today large central power plants send steam through tunnels under the sidewalks to heat a number of buildings in downtown areas or on Montana university campuses. But geothermal energy can be used to replace the steam and hot water needed in conventional district heating systems. Today, cities including Boise, Idaho and Klamath Falls, Oregon use geothermal water from wells instead of steam to heat groups of buildings. Montana communities including Baker and Poplar have conducted feasibility studies on geothermal district heating systems.

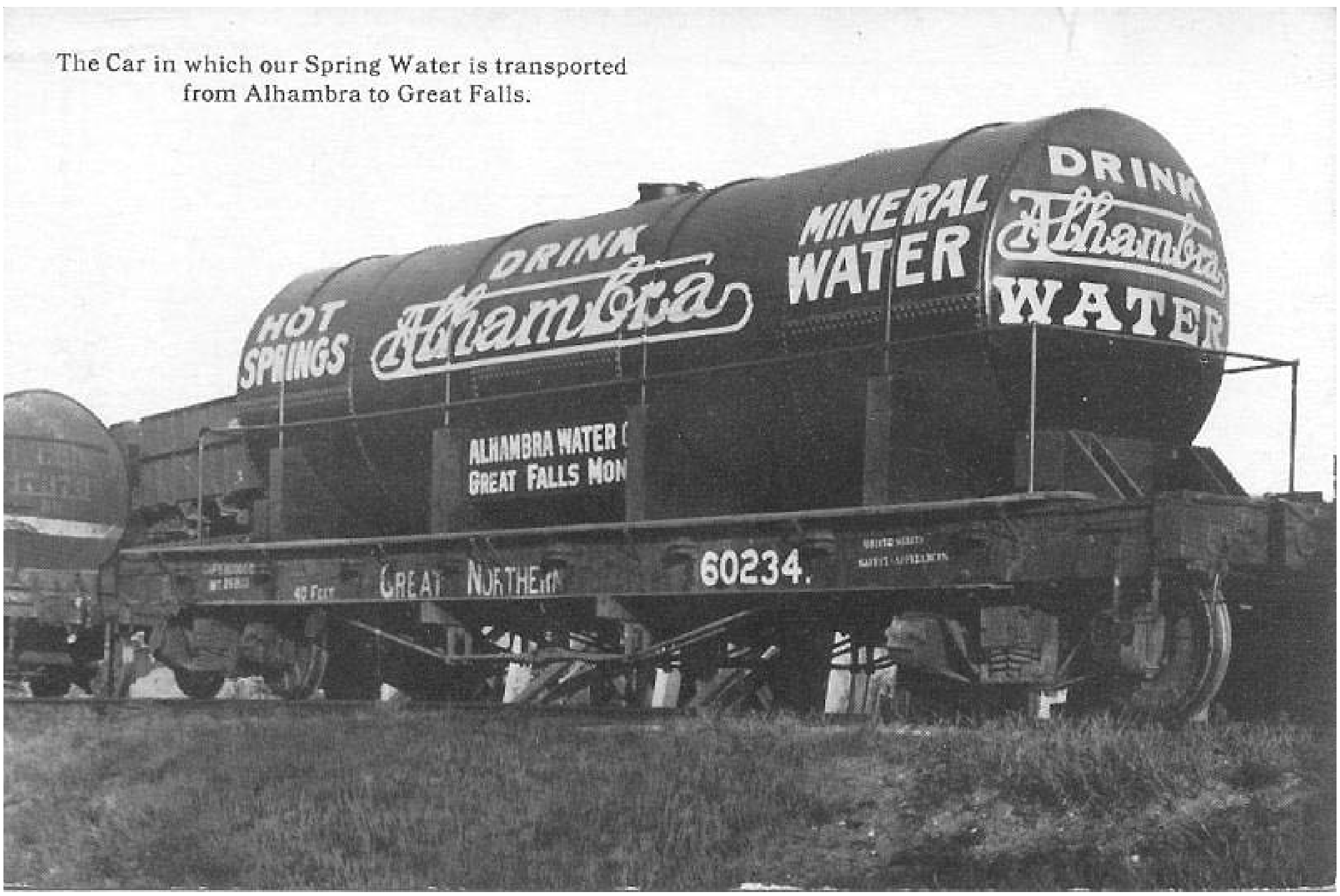
Geothermal water is piped for miles to heat buildings in downtown Boise, Idaho. Plastic pipe wrapped in special insulation reduces heat loss as the hot water flows from the geothermal well to the district heating system.

Photo by Jeff Birkby

11. Industrial Uses

The heat from geothermal water is used worldwide for industrial purposes. Some of these uses include drying fish, fruits, vegetables, and timber products; washing wool, dying cloth, and pasteurizing milk. Geothermally heated water can be piped under sidewalks and roads to keep them from icing over in freezing weather. Thermal waters are also used to help extract gold and silver from ore and even for refrigeration and ice-making. Dehydration, or the drying of vegetable and fruit products, is the most common industrial use of geothermal energy.

In the 1980s an engineering firm developed plans to use geothermal water from a well at Wild Horse Hot Springs to preheat an ethanol production process. Thirty years later research was conducted on using low-temperature geothermal energy in the town of Hot Springs to grow algae that could then be processed into a biofuel.



At least two of Montana's early hot springs resorts (Alhambra and Hunter's) found markets for their hot springs mineral water in cities throughout the United States.

Photo — University of Montana Archives

12. Electricity Generation

Oil and gas wells such as those in eastern Montana are typically thousands of feet deep, and often produce very hot fluid. Most oil and gas wells produce large quantities of hot water that have to be separated from the fossil fuel. This waste water is usually reinjected deep below domestic aquifers. But new technologies have been developed that may allow the hot water from Montana's oil wells to be used to economically generate electricity.

For several decades Montana was thought to have little potential for producing electrical power for geothermal energy. Although several wells in eastern Montana produce water between 200 and 270 degrees F, electric generation technology in the past required water in the 300 degree F range or above.

This hot water well located near the town of Angela, north of Miles City in eastern Montana, produces 185 degree F water. Brilliant white terraces of mineral deposits are shown in the photo above.

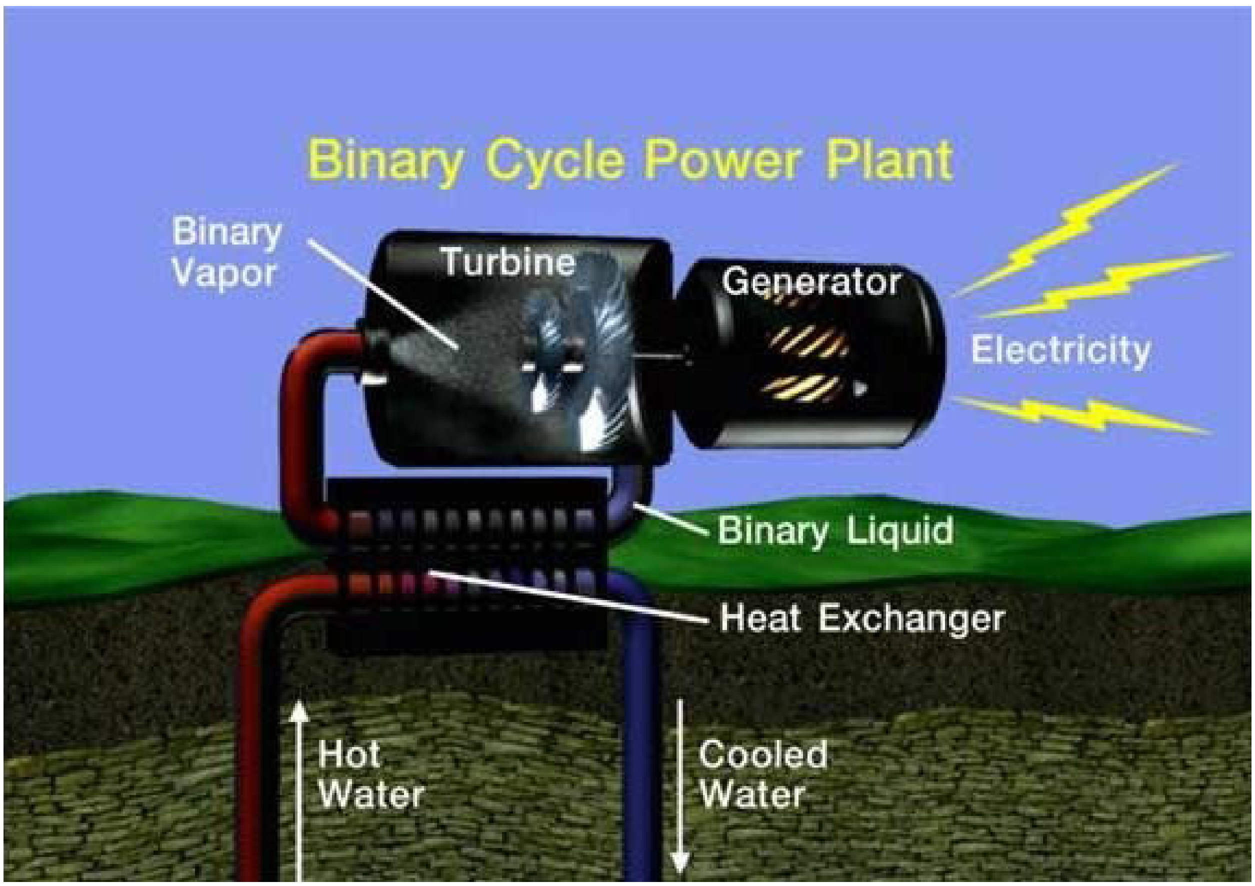
Photo by Jeff Birkby

Since the mid 1990s, breakthroughs in geothermal system designs using new turbines and secondary fluids have significantly lowered the temperatures needed for power generation. Geothermal fluids as cool as 165 degrees F are now being used for electric power generation in Alaska. And these lower geothermal temperatures are available in many areas in Montana, which opens up the possibility of geothermal electrical generation in the near future in the state.

12. Electricity Generation – *continued*

Newer geothermal electric generation systems, called binary cycle plants, do not directly use geothermal fluids to run a turbine. Instead, these power plants use heat exchangers to extract the energy from the geothermal water that is pumped to the surface. The hot water is used to boil a second fluid that has a boiling point much lower than that of the hot water coming out of the well.

After the vaporized secondary fluid passes through the turbine blades to generate electricity, the vapor is cooled with cold water or with outside air, which turns the vapor back into a fluid. The fluid is then recycled through the loop. The cooled geothermal water is usually pumped back into the ground after it passes through the heat exchanger.



Schematic Diagram of a Binary Cycle Geothermal Power Plant.

Source: National Renewable Energy Laboratory

Binary power plant technology is constantly evolving, and new transfer fluids are being investigated; this research will allow lower temperature resources to be used to produce electricity in the future.

12. Electricity Generation – *continued*

Research and demonstration programs using geothermal fluids from oil wells could lead to significant new developments of geothermal energy in Montana and other western states. An operating binary geothermal plant is being demonstrated at the Rocky Mountain Oil Testing Facility near Casper, Wyoming, and a new demonstration plant is under design just across Montana's eastern border in North Dakota.

Montana also is examining these promising new geothermal opportunities. In late 2011 the Flathead Electric Cooperative began drilling an exploration well near the town of Hot Springs, Montana in search of sufficiently hot water to use in a binary generator. And in 2012 a federally-funded feasibility study on using geothermal water from oil and gas wells is being conducted on the Fort Peck Assiniboine and Sioux Tribes Reservation in northeast Montana.

A binary generator at the Rocky Mountain Oilfield Testing facility near Casper, Wyoming. This power station uses 195 degree F water from an oil well to generate 250 kW of electricity.

Photo by Jeff Birkby

12. Electricity Generation – *continued*

A small binary generator that will use geothermal fluids from an oil well is being evaluated at the Rocky Mountain Oilfield Testing Center near Casper, Wyoming.

Photo by Jeff Birkby

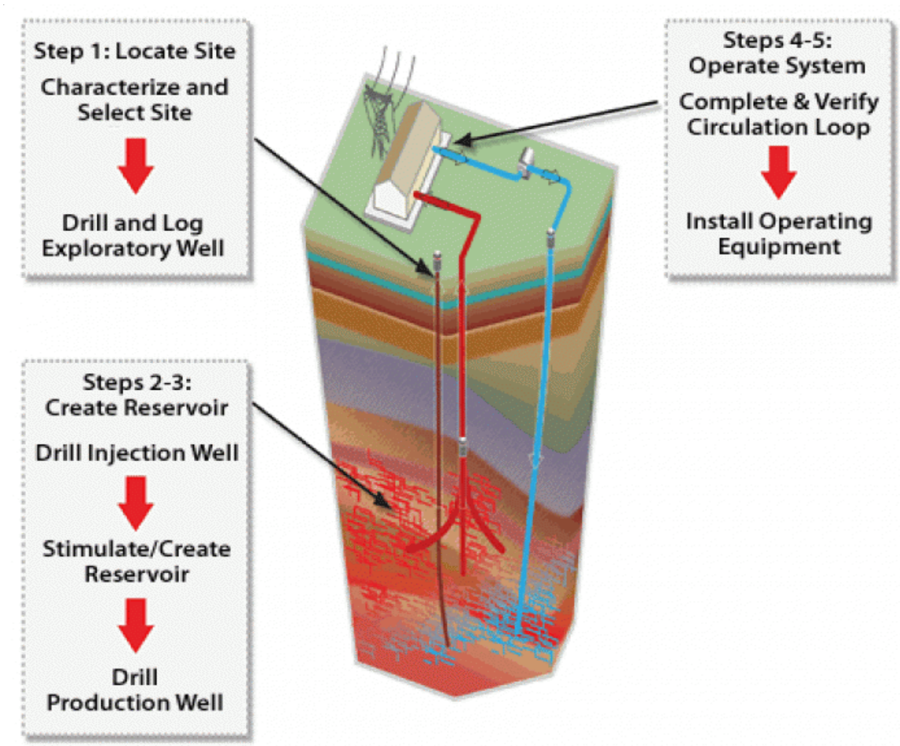
Enhanced Geothermal Energy Systems (EGS)

Natural geothermal systems occur in only a few special places where geologic conditions provide access to hot water at or near the surface. But enhanced (or engineered) geothermal systems open up the possibility of extracting heat from deep, hot but naturally dry rock. In this scenario two deep wells are drilled, pressurized fluids are injected into both wells, and existing cracks in the rocks between the wells are opened. The wells are typically drilled to depths of 2 to 6 miles. These Enhanced Geothermal Energy Systems (EGS) require deeper drilling, hydro-fracturing, and use of fluids to bring the heat to surface.

A significant barrier to EGS is the availability of water. Finding water to charge and maintain the initially dry reservoir of an enhanced geothermal system can be challenging in an arid environment. Although this system is nominally a “closed loop,” small to moderate amounts of water are lost into the fractured reservoir.

In Montana, EGS systems are still far in the future — using geothermal coproduction from existing oil and gas wells in the near term is more likely and more economical. But if drilling technology continues to improve, perhaps someday much more of the deep geothermal heat underlying Montana will be accessible for power generation.

EGS Development Sequence



13. Cascaded Uses of Geothermal Energy

Geothermal projects can be "cascaded," which mean the same geothermal fluid is used for multiple purposes, thereby increasing the operation's economics. A food company in Nevada uses geothermal resources to generate electricity, and then cascades the hot water from the power plant to a facility where it is used to dehydrate 26 million pounds of dried onion and garlic annually. Many spas and resorts use the same geothermal fluids for building heating, laundry and hot water heating, and swimming pools. An agricultural operation in Oregon has used its geothermal resource to grow bedding plants and perennials, heat buildings and greenhouses, wash equipment, mix the warm water with chopped hay to feed calves, raise tropical fish, and then provide water to thirsty cattle.

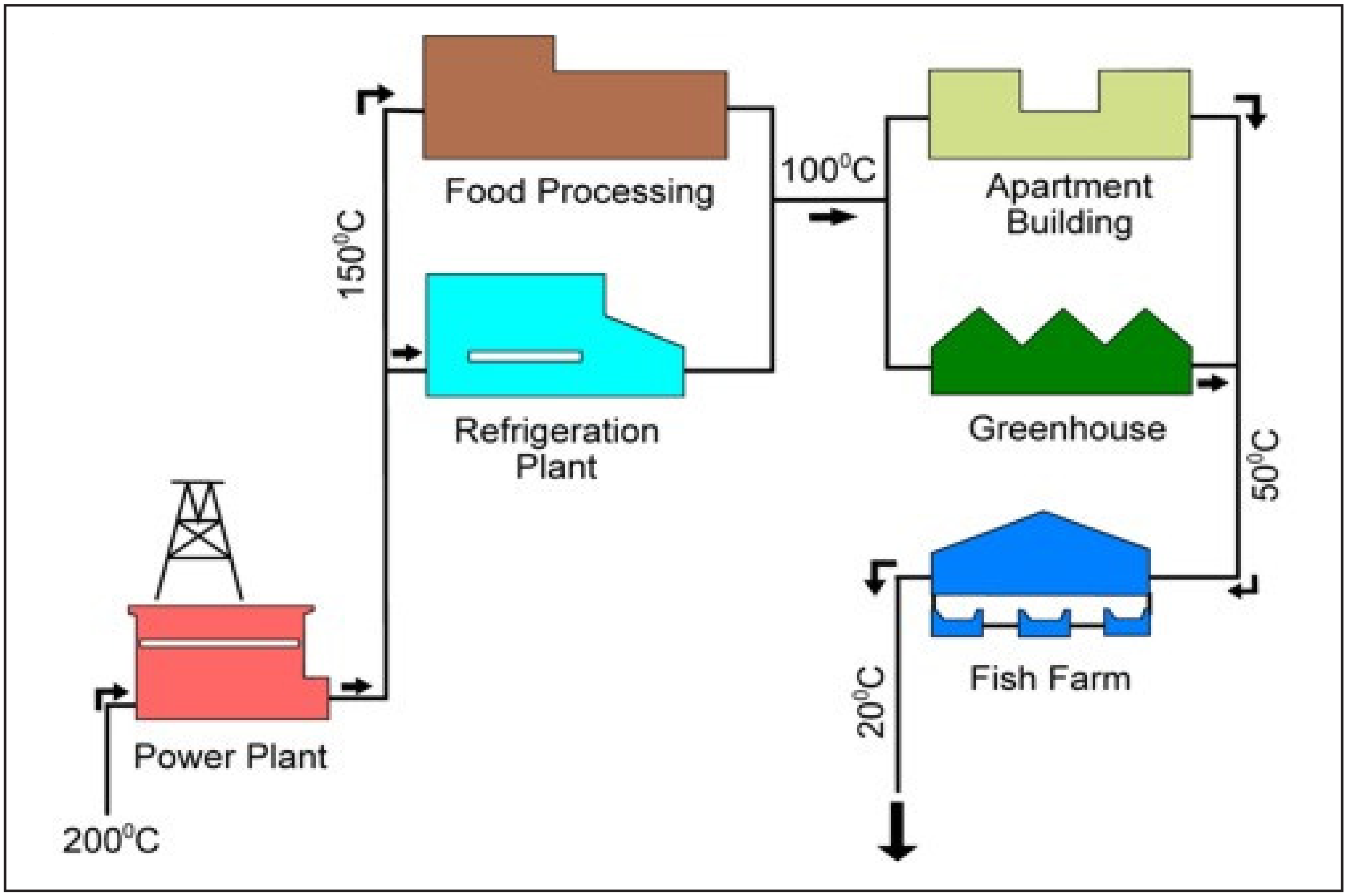


Diagram of Cascaded Uses of Geothermal Energy.

Courtesy Geo-Heat Center, Klamath Falls, Oregon

Montana has a few examples of cascaded uses of geothermal energy. At Boulder Hot Springs, geothermal water feeds the outdoor swimming pool and heats the hotel. The thermal water then cascades to warm water ponds where tropical fish are raised for use in mosquito control. Chico Hot Springs Resort uses its hot springs water for pool heating, space heating, and then finally for heating a greenhouse where lettuce and other produce is grown year-round for use in their restaurant.

14. Legal Issues for Montana Geothermal Development

[This chapter adapted from ***A Regulatory Guide to Geothermal Direct Use Development — Montana,*** published by the Washington State University Extension program in 2004.]

The state of Montana does not have a unique Geothermal Resources Act, as can be found in many other western states. In Montana, specific statutes regarding geothermal resources are contained in *Title 77– State Lands, Chapter 4 – Geothermal and Hydroelectric Resources, Montana Code Annotated.* These statutes also address the leasing of state or school lands for geothermal resource development.

These statutes define “geothermal resources” in Montana as “*the natural heat energy of the earth, including the energy, in whatever form, which may be found in any position and at any depth below the surface of the earth, either present in, resulting from, created by, or which may be extracted from such natural heat and all minerals in solution or other products obtained from the material medium of any geothermal resource.”*

Montana further characterizes geothermal resources as *sui generis* (77-4-104, MCA), “*being neither a mineral resource nor a water resource, but closely related to and possibly affecting and affected by water resources in many instances.”*

Title 77, Chapter 4, section 108 of the Montana Code Annotated additionally states: “*If any geothermal development located on state land requires the utilization of water, the lessee may, at any time prior to 1 year before the expiration of his lease, make application to the board for permission to secure a water right to the land under his lease. Such application shall be in writing, show the permanency of the water supply, and the estimated cost of utilizing such water resources. If the proposed plan meets with the approval of the board, permission shall be granted to the lessee to secure the desired water right for the land. Such right shall be secured in accordance with Title 85, chapter 2, and shall be filed in the name of the state. Existing water rights purchased by the geothermal lessee shall be the property of the lessee.”*

What these statutes imply is that geothermal resources in Montana are to be regulated as water. As a result, low temperature, direct use geothermal projects, including greenhouse heating, warm water aquaculture, space heating, swimming pool use, and spas are regulated in accordance with the rules and statutes governing ground water appropriation and well drilling regulations. A developer must acquire the water resource by means of an application, permits, and license procedure.

Drilling a hot water well at the Montaqua Mineral Health Resort near Joliet, Montana, circa 1940.

Photo — Author’s personal collection

14. Legal Issues for Montana Geothermal Development – *continued*

The regulations governing Montana geothermal projects differ from conventional water development projects in that direct use projects may need to dispose of the water once it has been used for its design application. Hot water disposal is typically accomplished through direct injection of the geothermal water via an injection well, or through surface disposal to the ground or to surface waters if injection is not an option. Montana also has special reviews for surface disposal of thermal waters into blue ribbon fishing streams and rivers, where fisheries might be damaged if the river water temperature rises too high.

The Montana Department of Natural Resources and Conservation (DNRC), is the lead agency in charge of administering and enforcing the various rules and regulations governing water use in the state of Montana. The agency is responsible for issuing water rights and well construction permits.

The U.S. Environmental Protection Agency, Region 8, oversees the administration of underground fluid injection wells in Montana.

The Montana Department of Environmental Quality (DEQ), is responsible for administering surface disposal of wastewater, including geothermal fluids.

The Bureau of Land Management (BLM) manages geothermal leasing on federally-managed public lands in Montana. Obtaining a geothermal lease is the first step for a company or individual before eventually applying to develop and produce geothermal resources. Additional planning, environmental analysis, and public input must occur before drilling can begin. There are no federal geothermal leases or current activity within Montana and only one nomination for a geothermal lease has occurred on federal land in Montana over the past 20 years. BLM formed a Renewable Energy Team in late 2010 to facilitate the development of renewable energy projects on BLM-administered public lands in Montana. More information on BLM geothermal leasing policies is available at the following website: http://www.blm.gov/mt/st/en/prog/energy/renewable.html#Geothermal

In addition to state and federal agencies, local and county agencies may also play a role in issuing local zoning and construction permits, and should be contacted early on in the development of a geothermal heating project.

Electric generation using geothermal energy requires significantly more review and permitting under Montana and federal laws. Montana's Major Facility Siting Act was modified in 2009 to exempt geothermal power plants in Montana that are capable of producing less than 50 megawatts of energy.

REGULATORY CHECKLIST for DIRECT USE of GEOTHERMAL ENERGY in MONTANA

- ✓ Gain access to lands either through lease or direct ownership.
- ✓ Contact local and/or county agencies to ensure compliance with local land use laws including building permits and zoning restrictions.
- ✓ Secure water rights. **(Montana DNRC)**
- ✓ Obtain well construction permit/develop production well or hot spring. **(Montana DNRC)**
- ✓ Determine fluid disposal plan and obtain permits for either underground injection or surface disposal. **(EPA, Montana DEQ)**
- ✓ Obtain well construction permit/develop production well or hot spring. **(Montana DNRC)**
- ✓ Determine fluid disposal plan and obtain permits for either underground injection or surface disposal. **(EPA, Montana DEQ)**
- ✓ Obtain relevant permits if developing an aquaculture project (**Montana Department of Fish, Wildlife & Parks)**

15. Financial Support for Geothermal Development

Montana has a variety of financial tools to help defray the cost of geothermal systems. A few of these are listed below. In addition, local utilities often have their own rebate programs for heat pump installations. Contact the Montana Department of Environmental Quality and your local utility for more information on the most current financial credits available for geothermal and other renewable energy systems.

Geothermal System Credit
15-32-115, MCA

Eligibility:
Resident individuals

Qualifying Expenditures:
Installation cost including such cost, but not limited to, trenching, well drilling, casing, ground source pumps, ductwork, and design and labor.

Benefits:
The maximum credit for the installation of a geothermal system in a taxpayer's principal dwelling cannot exceed $1,500. The unused amount may be carried forward for seven succeeding tax years.

Alternative Energy Production Credit
15-32-401 through 15-32-407, MCA

Eligibility:
Individual, corporation, partnership, or small business corporation

Qualifying Expenditures:
Investment of $5,000 or more in depreciable property under the Internal Revenue Code for a commercial system or a net metering system located in Montana that generates energy by means of an alternative renewable energy source.

Benefit:
The credit is 35 percent of the eligible costs. The credit must first be claimed in the year in which the asset was placed in service; any excess credit may be carried over up to seven years. For wind energy investments 5 megawatts or larger, which are located within the exterior boundaries of a Montana Indian reservation, the credit may be carried over up to 15 years. (Please refer to MCA 15-32-402 and 404 for additional qualifications necessary regarding investments located on a Montana Indian reservation).

15. Financial Support for Geothermal Development – *continued*

Alternative Energy System Credit
15-32-201 through 15-32-203, MCA

Eligibility:
Resident individuals

Qualifying Expenditures:

- Nonfossil form of energy generation system such as wind energy, solar energy, solid waste, and decomposed organic waste in your principal home.
- Low emission wood or biomass combustion device, such as a pellet or wood stove in your principal home.
- Certain outdoor hydronic heaters or masonry heaters.

Benefits:
The credit for the installation of a recognized nonfossil form of energy generation system in the taxpayer's principal dwelling is the cost of the system, including installation costs, less grants received, not to exceed $500 per taxpayer against the income tax liability imposed. Any excess credit not claimed in the year of installation may be carried forward for four succeeding tax years.

16. Further Information, Contacts, and Publications on Geothermal Energy

Montana Contacts

Montana Geothermal Program
Montana Department of Environmental Quality
1100 North Last Chance Gulch
P.O. Box 200901
Helena, MT 59620-0901
http://deq.mt.gov/Energy/geothermal/default.mcpx

Groundwater Information Center
Montana Bureau of Mines and Geology
Montana Tech of the University of Montana
1300 West Park Street - Natural Resources Building, Room 329
Butte, MT 59701-8997
Phone: (406) 496-4336 Fax: (406) 496-4343
http://mbmggwic.mtech.edu/sqlserver/v11/menus/menuProject.asp?mygroup=GEOTHERM&

Montana Department of Natural Resources
Billings Oil & Gas Conservation Division
2535 St. Johns Avenue
Billings, MT 59102
Phone: (406) 656-0040 Fax: (406) 656-0040
http://dnrc.mt.gov/FieldOperations/OilGas/billings.asp

Other Contacts

Oregon Institute of Technology's **Geo-Heat Center** is perhaps the most useful and complete site for direct-use and small-scale development of geothermal energy. The Geo-Heat Center is an excellent source of technical information on project designs for low and moderate temperature resources. The Center's website includes an interactive direct-use map, information on co-located resources, and a database on geothermal wells and springs for the western states. The center also has downloadable technical papers and bulletin articles on many geothermal applications. http://geoheat.oit.edu

The **Geothermal Energy Association** has extensive information and literature for existing and planned power plants. The association's website includes power plant locations, capacities, cost structures and contact information. The organization also hosts an annual Geothermal Energy trade show that runs in conjunction with the Geothermal Resources Council Annual Meeting. www.geo-energy.org

The **Geothermal Resources Council** has a searchable library of articles from a variety of publications on all aspects of geothermal development worldwide. The GRC also sponsors one of the major geothermal energy conferences every year, attracting more than 2,000 attendees from around the world. www.geothermal.org

16. Further Information, Contacts, and Publications on Geothermal Energy – *continued*

The **National Renewable Energy Laboratory's Geothermal Technologies Program** offers in-depth reports on the status and future of geothermal electric power generation as well as a description of geothermal energy program highlights. *The U.S. Geothermal Industry: Three Decades of Growth* provides an excellent historical perspective on geothermal energy. This website also has an extensive database of more than 600 pictures of geothermal images. http://www.nrel.gov/geothermal/

Other Relevant Websites:

Southern Methodist University Geothermal Laboratory
www.smu.edu/geothermal

U.S. DOE Geothermal Technologies Program
www.eere.energy.gov/geothermal

Great Basin Center for Geothermal Energy
www.unr.edu/geothermal/links.html

University of North Dakota Geothermal Laboratory
www.geology.und.edu/

Idaho National Engineering and Environmental Laboratory (INEEL)
http://geothermal.inel.gov

Sandia National Laboratories Geothermal Research Department
www.sandia.gov/geothermal

International Ground Source Heat Pump Association
www.igshpa.okstate.edu

GeoExchange, Geothermal Heat Pump Consortium
www.geoexchange.org

Publications

Geothermal Direct-Use Engineering and Design Guidebook
The Third Edition of this publication provides technical information on low- and moderate-temperature (100 - 300° F) geothermal applications and equipment. Chapters cover exploration, well drilling, space heating and cooling, greenhouse heating, aquaculture, industrial processes, economics, regulations and environmental aspects.
https://www.oit.edu/Storefront/geoheat/ItemDetails.aspx?ItemID=12

Geothermal Greenhouse Information Package
Tonya Boyd
Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, OR
http://geoheat.oit.edu/pdf/green.pdf

16. Useful Information, Contacts, and Publications on Geothermal Energy – *continued*

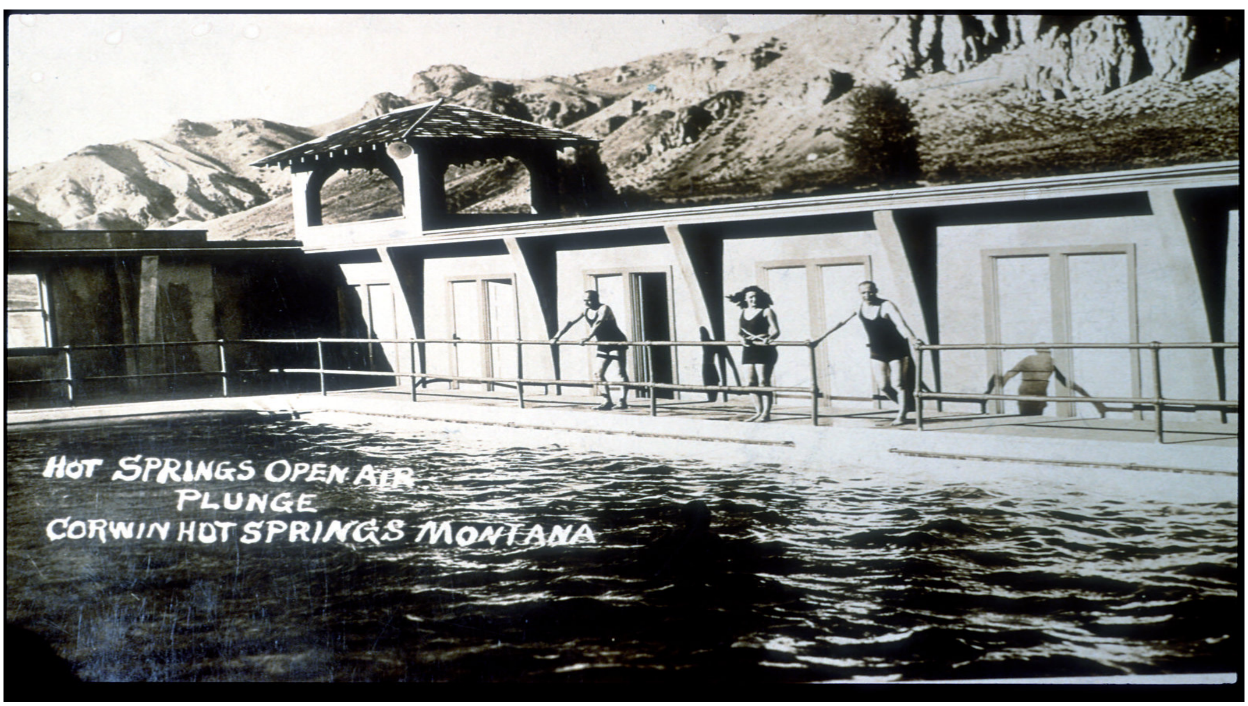
Publications – *continued*

Aquaculture Information Package
Tonya Boyd and Kevin Rafferty
Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, OR
http://geoheat.oit.edu/pdf/aqua.pdf

Geothermal Small Business Workbook
Liz Battocletti
Bob Lawrence & Associates, Inc.
May 2003
http://www.geothermal-biz.com/GSBW.pdf

An Introduction to Geothermal Permitting
Liz Battocletti
Bob Lawrence and Associates, Inc.
November 2005
http://www.geothermal-biz.com/Docs/Intro_to_geo_permitting.pdf

Lava Law: Legal Issues in Geothermal Energy Development
Stoel Rives LLP
February 2009
http://www.stoel.com/showarticle.aspx?Show=2279



The outdoor plunge at Corwin Hot Springs, about ten miles north of Yellowstone National Park, circa 1940.

Photo — Author's personal collection

Appendix 1

Some Potential Advantages of Electricity Power Generation from Montana's Geothermal Resources

✓ **The availability of geothermal power resources in Montana will increase.**
Many oil wells in eastern Montana produce not only oil, but also sizeable quantities of hot water at temperatures sufficient to run small binary cycle turbines to generate electrical power. While the geothermal energy resource at any one oil well is likely to be small (less than a megawatt), aggregating the wells in a large oil field could produce significant power at low cost, since the wells have often already been drilled for oil and gas production. In addition, the technology for generating electricity from geothermal energy is constantly improving, and price drops for this equipment should continue.

✓ **Geothermal power is reliable.**
Electricity generated from geothermal energy is a preferred type of energy known as "base load power." This base load power from electrical generation is always "on" or always available at the flip of a switch. Existing geothermal power plants in the western United States have a "capacity factor," or availability, of 85 to 95 percent or more, which is well above the capacity factor for coal power plants or other traditional base load power generators. Very little goes wrong with a geothermal power plant — often they only need to shut down for a day or two a year for normal maintenance. A properly designed and sited geothermal power plant takes advantage of deep reservoirs of hot water under pressure. These geothermal energy reservoirs, if properly managed, will provide the thermal energy needed for power generation for years into the future.

✓ **Electricity produced from geothermal energy is one of the cheapest sources of power available**.
The price of geothermal power is comparable to that of wind power, new coal plants, or biomass. While considerable investments may be needed to discover and assess geothermal resources, the power generation equipment available today is modular, quick to install, and fairly easy to operate. And if geothermal resources from existing oil and gas wells can be used, the economics are even more attractive, since no news wells need to be drilled.

✓ **Geothermal power systems have a small environmental footprint.**
Where solar and wind farms gather energy over large areas, a geothermal plant gathers heat from the hot rock or fluids below ground by means of one or a few wells. The footprint of the generator and associated pumps and cooling tower would be much smaller than the footprint of a coal fired plant generating the same amount of power. And most geothermal systems are "closed-loop," with only the heat energy extracted from the water. No geothermal fluids are exposed to the atmosphere, and there are almost no emissions of carbon dioxide or other pollutants. The fluids are simply pumped to the surface, the heat is extracted, and then the fluids are returned via an injection well to a permeable layer beneath the earth's surface.

✓ **Geothermal energy is a renewable resource**.
After the heat is extracted from geothermal water for power generation, it is reinjected into the earth where it can be heated again by the earth's natural temperature gradient.

Adapted from *Geothermal, the Other Baseload Power*
www.altenergystocks.com/archives/2007/10/geothermal_the_other_base_load_power.html

Appendix 2

Feasibility Checklist for Montana Geothermal Electricity Generation

There are four areas to consider when evaluating the potential success of an electrical power generation project using Montana's geothermal resources:

1. **Geologic Issues – Does the resource exist?**
2. **Legal Issues – Can the resource be legally harnessed?**
3. **Engineering Issues – Can the resource be efficiently harnessed?**
4. **Financial Issues – Can the project be financed? Does it make sense economically?**

These four areas are discussed in detail below:

1. Geologic Issues — Does the Geothermal Resource Exist?

This is the starting block for any Montana geothermal venture, simply because you need to identify a geothermal resource and its characteristics before you can develop it.

- ✓ What is the geology of the area?
- ✓ Are any local well logs available?
- ✓ Is seismic information available?
- ✓ Is a chemical analysis of the fluids available?
- ✓ What is the current knowledge of the geothermal resource?
- ✓ Where is the geothermal resource, at what depth, in what geologic formation?
- ✓ What is the temperature, pressure, formation thickness, and flow rate of the resource?
- ✓ What is the estimated size and producing potential of the formation?
- ✓ Are there geological risks involved?
- ✓ Seismic or other geologic factors that may present a risk to wells and production.
- ✓ What is the produced water chemistry, i.e., amount of total dissolved solids, pH, and mineral content?
- ✓ What is the likelihood of cooling the formation when it is pumped?
- ✓ Is the geothermal resource sustainable on a long-term basis?
- ✓ Does the resource replenish itself naturally, or is injection into the original formation necessary?
- ✓ Where should an injection well be located as to not thermally impact the reservoir?
- ✓ How long is the reservoir expected to sustain production rates – 10, 20, 30, 100 years?
- ✓ Where will the produced fluids be dispensed?
- ✓ At what depth will the fluid be reinjected?
- ✓ What is the chemistry of the formation that is being injected into?
- ✓ What is the risk posed by production fluid chemistry?
- ✓ What's the size of the disposing formation?
- ✓ Are there geological risks related to disposing into this formation?
- ✓ Can the spent fluids be used for secondary recovery?
- ✓ Will coproduction of hydrocarbons and geothermal fluids from the same well occur?
- ✓ Is there oil, gas, or both in the production formation?
- ✓ Have you reviewed all relevant geologic and water resource records from Montana agencies, including DEQ, MBMG, and DNRC?

Appendix 2 – *continued*

2. Legal Issues — Can the Geothermal Resource be Legally Harnessed?

Legal issues often become some of the greatest obstacles in the development of many geothermal ventures. A thorough legal analysis will clearly identify potential issues with the site, amount of power produced, or other issues that could pose serious threats to the project. In the United States, the highest quality geothermal fields, such as in Yellowstone National Park, are closed to all development.

- ✓ Is the resource in an area that can be developed?
- ✓ What Montana state, county, and city permits are needed?
- ✓ Can you drill/inject in this area?
- ✓ What zoning laws exist that could impact the project?
    - noise bans,
    - visible emission bans,
    - aesthetic rules and regulations?
- ✓ What are the governing bodies of the area?
    - Federal, tribal, Montana, local
    - Utility company service territories
- ✓ What protocols are required in order to legally produce and sell power in your area?
- ✓ What is the interconnectivity charge to load your power onto the grid?
- ✓ How do you get the rights to the resource?
- ✓ Who owns the mineral rights?
- ✓ Who owns the surface land rights?
- ✓ How much will it cost to get the rights?
- ✓ What environmental rules exist that could benefit or threaten your project?
- ✓ Do any tax credits, stimulus packages, or other incentives exist that your project could benefit from?
- ✓ What are the environmental laws regarding drilling and fluid reinjection?
- ✓ What are the environmental laws regarding air emissions?
- ✓ What hydrocarbon rules exist that could impact your project?

3. Engineering Issues — Can the Resource be Efficiently Harnessed?

Once your chosen geothermal resource in Montana is well understood, you need to find the most efficient way of harnessing its full potential in order to maximize power plant output as well as economic return.

- ✓ What type of plant design and system is best suited for harnessing the resource? (Dry steam, flash steam, or binary power generation plant?)
- ✓ Will the temperature, pressure, and fluid flow rate of my reservoir be able to support one of these plants?
- ✓ What diameter wells and pipes do I need to produce my desired amount of energy?
- ✓ How many wells do I need to obtain my desired fluid flow rate to maximize power plant output?
- ✓ What insulation is needed in order to most efficiently transport the heat?
- ✓ What material should my casing/pipes be made of to avoid corrosion, scaling, or other impurity related issues?
- ✓ To what extent is reservoir engineering required in your resource?
- ✓ Do you need to fracture the formation in order to increase production?
- ✓ What working fluids will be involved in the plant operations (including refrigerant fluids if using a binary turbine system)?

Appendix 2 *– continued*

3. Engineering Issues — Can the Resource be Efficiently Harnessed? *– continued*

- ✓ How much cooling fluid is needed and where will it come from?
- ✓ In the wells, pipes, and plant systems, what chemicals will be used to eliminate issues of scaling?
- ✓ What electrical, computer, and other systems are required in order to run the plant at its highest efficiency?
- ✓ What personnel will be needed to run the plant?
- ✓ What backup/emergency systems will be installed in the case of a malfunction?
- ✓ How will I transport the energy from the plant to the desired market?
- ✓ Where is the closest utility transfer station?

4. Financial Issues — Can the Project be Financed?

Answering this question will be the true "make or break" test of your Montana geothermal power generation venture. If the budget numbers don't make sense, then the geothermal project won't make sense.

Opportunity Analysis

- ✓ Who is going to buy your energy?
- ✓ What is the most profitable target market for the generated power: selling to the grid, distributed energy, coproduction, a combination?
- ✓ If gas or oil is produced in a coproduced well, will it be sold to a pipeline, used in a fuel cell, or used in a turbine?
- ✓ How much energy is needed to satisfy the energy needs of the binary generator?
- ✓ Can a Power Purchase Agreement be secured? At what price, for how long?
- ✓ How will this project be financed (debt/equity)?
- ✓ What is the source of capital?
- ✓ What is the cost of capital?
- ✓ What financial risks are associated with the project?
- ✓ What is the anticipated plant performance?

Profit Analysis

- ✓ What is the estimated Cost of Capital?
- ✓ Where will the funding come from?
- ✓ What is the Net Present Value?
- ✓ What is the Future Value?
- ✓ What is the Required Rate of Return?
- ✓ What discount rate is used to account for risk?
- ✓ How many years does the project need to be in production to produce the required rate of return?
- ✓ How dependent are the estimates based on commodity prices?
- ✓ What is the effect of raising or lowering commodity prices?
- ✓ Are there government incentives that may affect the calculations?
- ✓ How much do I expect to make from the project?
- ✓ What is the project timeline?
- ✓ What are the risks associated with not being on schedule?
- ✓ Given the calculations, the expected budget, and the potential payback, does the project make financial sense?
- ✓ Is there a potential for "cap and trade"/carbon-credit earnings for this project?
- ✓ Can you include the earnings from oil/gas sales if using geothermal energy from existing oil/gas wells?

Appendix 2 *– continued*

4. Financial Issues — Can the Project be Financed? *– continued*

Cost Analysis

What are the exploration and development costs?

- ✓ Seismic surveys, well logs and data, geologic analysis, chemical analysis of geothermal fluids, etc.
- ✓ Short and long term flow tests, disposal and/or reinjection tests?
- ✓ What are the drilling costs? What are the costs for the drill rig, well fracturing, personnel, casing, etc.?
- ✓ Can you recomplete an existing well?
- ✓ What is the cost to recomplete a well?
- ✓ What is the lifespan of a well?
- ✓ New production well: drilling costs, casing costs, emplacement of the wellhead, preparing the site for power plant installation.
- ✓ Existing production well: work-over costs of well, perforation of casing, formation fracturing.
- ✓ Injection well designed and drilled to necessary depth, casing, injection pump, etc.

What are the legal costs?

- ✓ Legal costs associated with zoning, siting, drilling permits and mineral right procurement.
- ✓ Legal costs associated with rules and regulations of how to properly case and prepare a well for production use.
- ✓ What are the permitting costs and procedures?

What are the development costs for infrastructure on and off site?

- ✓ Purchase (or design and manufacturing) of the power plant, shipping, and installment costs.
- ✓ Connection of pipes to other necessary infrastructure to the plant (separator, injection well, sound muffler, etc).
- ✓ What are the installation costs for equipment, transmission wires and cables, cost of machinery, and personnel to install and test run the plant?

What are the production costs?

- ✓ Taxes and interconnection tariffs?
- ✓ Cost of day-to-day plant operation, obtaining personnel?
- ✓ What are the operation and maintenance costs associated with running the plant?
- ✓ Costs of routine yearly maintenance and monitoring, chemicals for injection, and to prevent scaling and corrosion?
- ✓ What is the total budget for fully developing the resource, completing the project, and running it over a specific time frame.

Adapted from "Questions to Consider Before Starting a Geothermal Venture," by Maria Richards, Southern Methodist University, 2009. www.smu.edu/geothermal

About the Author

Jeff Birkby's interest in Montana's thermal waters began more than 30 years ago when he was hired as a geothermal energy specialist for the Montana Department of Natural Resources and Conservation.

Birkby is author of *Touring Montana and Wyoming Hot Springs* and *Touring Oregon and Washington Hot Springs*, both published by Falcon Press.

As a member of Humanities Montana Speakers' Bureau, Birkby lectures around the state on the social history of Montana hot springs.

Birkby lives in Missoula, Montana, where he writes about hot springs and consults on geothermal energy projects. He also works on sustainable community and sustainable agriculture issues for The National Center for Appropriate Technology (NCAT).

Jeff Birkby can be reached at Birkby Consulting, LLC, 238 East Sussex Avenue, Missoula, Montana. Phone: (406) 493-6234 • email: jeff@birkbyconsulting.com • website: www.birkbyconsulting.com

Montana Department of Environmental Quality
Energy Publications

www.energizemontana.com

Energy Conservation Publications:

- Montana Energy Savers Guidebook - Practical Ways to Save Money & Improve Comfort
- DOE Energy Savers - Tips on Saving Energy and Money at Home
- Energy Notes - Energy Efficiency Through Demand Side Management
- Energy Notes - Mobile Homeowner's Guide to Saving Money and Energy
- Gas Furnaces and Appliances - Sorting Through the Options
- Residential Buildings Energy Code Summary

Renewable Energy and Bio-Fuels Publications:

- Alternative Energy Revolving Loan Program Brochure
- B20 Biodiesel Questions and Answers Brochure
- Montana BioEnergy Guidebook, available online at: http://deq.mt.gov/Energy/bioenergy/default.mcpx
- E10 Unleaded Gasoline Brochure
- Montana Wind Power – A Consumer's Guide to Harnessing the Wind
- Small Wind Electric Systems – A Montana Consumer's Guide

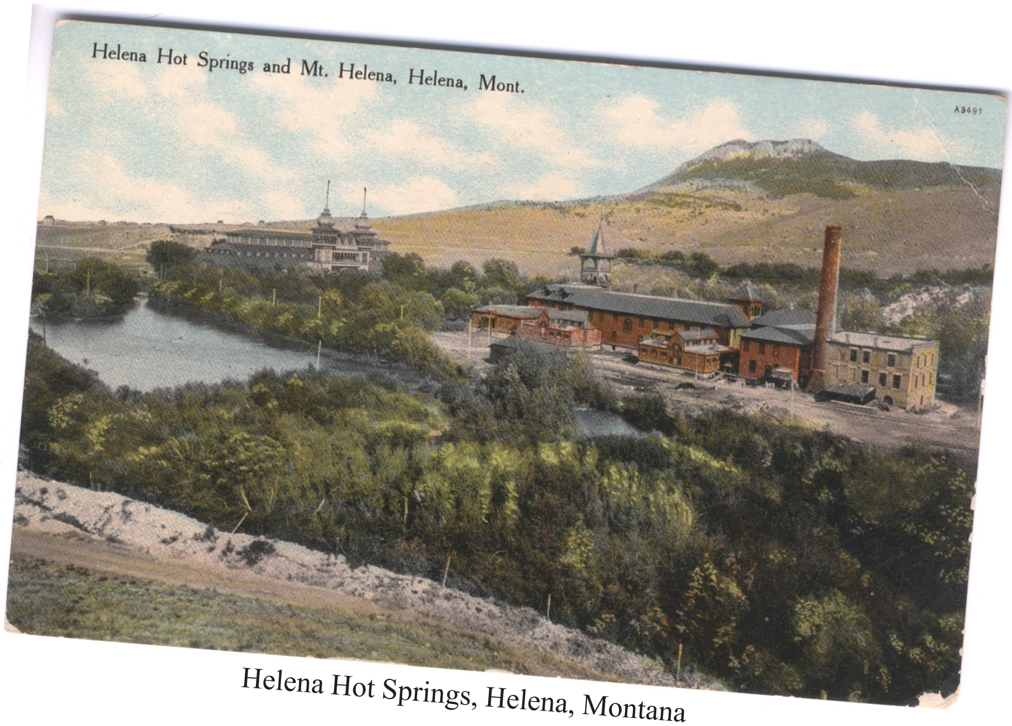
Montana Energy Fact Sheets:

- Montana's Energy Resources – Alcohol Fuel
- Montana's Energy Resources – Geothermal
- Montana's Energy Resources – Small Hydro

Radon Publications:

- A Citizen's Guide to Radon
- Home Buyer's and Seller's Guide to Radon
- Consumer's Guide to Radon Reduction
- Radon Mitigation Standards

Montana Department of
ENVIRONMENTAL
QUALITY



Helena Hot Springs, Helena, Montana

Boulder Hot Springs, Boulder, Montana

Broadwater Natatorium, Helena, Montana

Corwin Hot Springs Hotel, Plunge and Bath Houses, circa 1910

Water Labels

Hunter's Hot Springs
Mineral Water

White Sulphur Springs
Mineral Water Co.

To order copies contact the:
Energy Planning & Renewables Section
Montana Department of Environmental Quality
Energy & Pollution Prevention Bureau
1100 North Last Chance Gulch
P. O. Box 200901
Helena, MT 59620-0901