The Economic, Environmental, and Social Benefits
of Geothermal Use in Oregon

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Oregon has a long and rich history of utilization of its geothermal resources. Today, the documented direct uses of geothermal waters are related to space and district heating, snow-melting, spas and resorts, aquaculture, greenhouses, and agribusiness. The Geo-Heat Center estimates that there are over 600 direct use applications in Oregon, not including undeveloped hot springs. Boyd (2007) and Sifford (2010) provide excellent summaries of geothermal energy uses in Oregon, some of which are no longer operational, and others that have expanded their use. The first permanent geothermal power plant in Oregon was installed at the Oregon Institute of Technology Campus in 2010, and a handful of other geothermal power projects are currently under development at the time of this report.

A Brief Note on the Occurrence of Geothermal Resources in Oregon

With so many uses of geothermal energy in Oregon, it is helpful to describe their occurrence in relation to geologic province and geographic county. Figure 1 shows the nine major physiographic regions of Oregon, indicating the State's diverse geologic nature. Essentially, the eastern two-thirds of Oregon (beginning in the Cascades) has known or potential geothermal resources. Figure 2 is a map of Oregon counties.

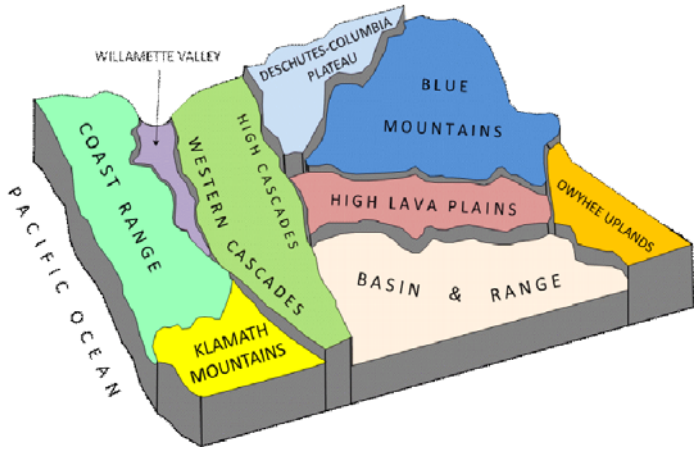

Figure 1. Physiographic regions of Oregon (reproduced from graphic by Elizabeth L. Orr, Geology of Oregon).

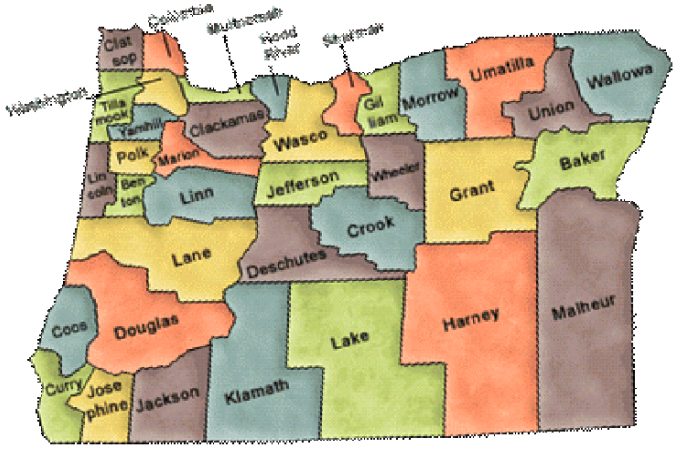

Figure 2. Map of Oregon Counties.

Justus et al. (1980) summarize the geologic provinces and the known geothermal resource areas (KGRAs) of Oregon. The geologic provinces include: the Cascade Mountains, the Basin and Range Province, High Lava Plains, Western Snake River Plain, and Northeastern Oregon. Each of these will be described below.

Economic benefits

Cascade Mountains: The Oregon Cascades are divided into two distinct belts: the Western Cascades and the High Cascades. The High Cascades are the easterly younger volcanic rocks, and are comprised of volcanoes such as Mount Hood, Mount Jefferson, and the Three Sisters (North, Middle, and South Sister). Another High Cascade peak, Mount Mazama, was destroyed about 6,800 years ago by a catastrophic eruption that left a deep caldera later filled by what is now Crater Lake. Mount Hood has been classified as a KGRA by the United States Geological Survey (USGS).

The Western Cascades are older, broader, and more deeply eroded relative to the High Cascades. Hot Springs occur in the Western Cascades in a relatively narrow zone nearly parallel to the axis of the range, possibly controlled by a north-trending fault. The major thermal springs from north to south are: Carey, Breitenbush, Belknap, Foley, and McCredie. Each of these has been classified as a KGRA by the USGS.

Clackamas County: Austin Hot Springs, located about 60 mi. from Portland is a very hot spring at 186^{o}F. The spring mixes with water from the Clackamas River in order to make it tolerable for soaking.

Bagby Hot Springs, located within the Mount Hood National Forest, is managed cooperatively by the Forest Service and a volunteer group, the Friends of Bagby. The hot water issues from two springs at about 136^{o}F, and is then channeled by wooden flumes into numerous bath houses and private tubs that are actually 10 feet long by 2-3 feet-diameter hollowed out cedar logs. The geothermal water mixed with cold water from nearby springs allows enjoyable soaking. Bagby Hot Springs was "discovered" by Robert Bagby, a miner from Amity, Oregon, in 1881. The Native Americans used the springs for centuries prior, and legend has it that there were no weapons permitted in the area of the springs so that they could be used for healing.

Figure 3. Cedar soaking tub at Bagby Hot Springs.

Jackson County: Jackson WellSprings is a 30 acre natural hot springs spa and events center located 1.5 miles from the Oregon Shakespeare Festival in Ashland. The facility specializes in mineral springs, swimming, hot water soaking and massage therapy. For centuries, Native

Americans have honored the warm springs on the banks of Bear Creek as a sacred ceremonial site. It is reported that warring nations put down their weapons in the vicinity of the hot springs. Applying for water rights in 1862, Eugenia Jackson dedicated the artesian waters to "sanitarium and natatorium purposes", and this is the mission of Jackson WellSprings. The naturally warm, spring-fed pools provide year around family swimming and soaking. A spacious warm water soaking pool is situated next to WellSprings nearly-Olympic sized swimming pool.

Figure 4. Soaking pool. www.jacksonwellsprings.com)

Lithia Springs, nestled in the convergence of the Siskiyou and Cascade mountains, a few miles from Ashland, is home to Lithia Hot Springs Resort. Historically, local Native Americans considered these lands and hot springs a "place of healing", and member tribes were welcome to bathe and partake of its healing waters, but all tribal differences had to be left outside. Today, Lithia Hot Springs Resort comprises four acres of arbors, Koi ponds, and English gardens. Geothermal mineral water is available in a variety of soaking tubs and whirlpools.

Lane County: Belknap is a well know commercial resort on the banks of the McKenzie River with two mineral hot spring pools. The facility offers a wide range of accommodations ranging from tent camping to lodge rooms.

Marion County: Breitenbush Hot Springs, Retreat and Convention Center is an abundant hot springs that have long been a destination for those seeking healing, rejuvenation and community. Three Meadow Pools are lined with smooth rocks and overlook a river. The four tiled Spiral Tubs are aligned in the cardinal directions with increasing temperatures. They are adjoined by the cedar tub cold plunge. The Sauna is a cedar cabin resting atop the bubbling waters. The cabins are heated year round with heat from the hot springs waters.

Figure 5. Historic lodge at Breitenbush, which has been operational for over 80 years.

Basin and Range Province: The Basin and Range Province is a vast physiographic region of the western United States that occupies portions of Nevada, California, Idaho, Utah and Arizona. The northern edge of the region lies in Oregon, occupying the south-central portion of the State. The region is characterized by its basin and range topography, which has resulted from tectonic

forces that have produced sequences of mountain ranges and downthrown fault blocks. Such fault blocks are often targets for geothermal exploration, and numerous thermal springs are found throughout this region.

This region has outstanding geothermal resources, and the USGS has classified five KGRAs: Klamath Falls, Lakeview, Summer Lake, Crump Springs (aka Crump Geyser), and Alvord Valley.

Klamath County: The City of Klamath Falls has the largest concentration of direct use geothermal applications in the United States, and is home to the Geo-Heat Center at the Oregon Institute of Technology (OIT). A retired mechanical engineer from Geo-Heat Center once remarked that in Klamath Falls, a person could live their entire life in geothermally-heated facilities: one could be born in a geothemally-heated hospital, be educated in geothermally-heated K-12 schools, see a doctor in a geothermally-heated medical clinic, swim in a geothermally-heated swimming pool, attend a geothermally-heated college (OIT), live in a geothermally-heated home, and end in a geothermally-heated funeral home. And in the meantime, if one accumulated too much junk, it could be stored in a geothermally-heated storage facility.

Historically, Native Americans used the hot springs located within the present Klamath Falls City limits for about 10,000 years. These springs were used to cook game and to heal various ailments. The most famous of these springs were "Big Springs" located in the present Klamath Union High School athletic field, and "Devils Tea Kettle" located near the present Ponderosa Middle School athletic field. "Big Springs" was used by the European settlers during the early 1900s for cooking and scalding meat, cooking vegetables, bathing, and just to keep warm (Lund, 1978).

Figure 6. Big Springs in early 1900s (source: Klamath County Museum).

In the 1890s local sheepherders dug holes in the ground to obtain hot water in areas adjacent to the artesian springs. Around the turn of the 20th century, homes were heated by direct-use of the artesian water, and both hot and cold water (after cooling in tanks overnight) were used for drinking and bathing. In 1925, residents started drilling wells using cable drilling methods in the area to the east of "Big Springs" in the Pacific Terrace area on the flanks of the large normal fault block that runs along the east side of the city. During the period from 1920 to 1932, plunger pumps were used on the dug and drilled wells due to the lack of knowledge concerning principles of thermosiphoning (or the natural convection movement of hot water) in a downhole heat exchanger. The first downhole heat exchangers were designed and installed by Charlie Leib, an Austrian immigrant, in 1931 utilizing the thermosiphoning principle (Lund et al., 1974; Fornes, 1981; Culver and Lund, 1999).

Today, approximately 550 individual residences in Klamath Falls take advantage of geothermal energy for home space and domestic hot water heating via individual wells drilled to depths

ranging from 200 to over 1000 ft, with average depths on the order of 350 ft. A handful of applications are "mini-district systems", with two or more homes sharing a single well. These wells extract geothermal energy with closed-loop downhole heat exchangers, with no groundwater removal from the well. At 2011 natural gas prices, Klamath Falls residents who use geothermal energy for home heating save an estimated combined $1.5 million per year in energy costs. These geothermal wells have periodic maintenance costs on average every 10 years, where the downhole heat exchanger may need replacing or sediment buildup in wells may need to be cleaned out.

Figure 7. Drilling and installing a downhole heat exchanger at a residence in Klamath Falls.

The Oregon Institute of Technology (OIT), since the early 1960s, has heated its entire campus with direct-use geothermal energy, and is the only campus in the world to obtain all of its heating needs (space + domestic hot water) from geothermal sources under its campus. In the 1970s, OIT also maintained a geothermally-heated greenhouse and small aquaculture operation that ceased due to lack of funds and need for more parking. Cooling of buildings on the OIT campus was once accomplished with a geothermal water-fired absorption chiller that was taken out of service in the mid 1990s and replaced with a conventional chiller. OIT recently added some new buildings on campus (the Dow Center for Health Professions and a new student village) in 2007-2009, increasing its total floor space to about 818,200 sq. ft. Heating the OIT campus with geothermal energy saves OIT $1 million annually. OIT also provides geothermal space heat to a neighboring retirement community. In addition to space heating of the OIT campus, OIT makes use of geothermal energy for snow-melting of about 40,000 sq. ft of sidewalks and stairways (Kieffer, 2011), saving about $125,000 annually in equivalent natural gas costs.

Figure 8. Geothermally snow-melted stairs at the OIT Campus in Klamath Falls, OR.

In 2010, OIT installed a 280 kW Pratt & Whitney geothermal electric power plant on campus, making it the only geothermal combined heat and power plant in the U.S., and the only university campus in the world to make use of geothermal combined heat and power. The plant generates about 1,750 MWh net electrical energy per year, saving the OIT over $100,000 annually. It is interesting to note that the geothermal power plant produces more than enough electricity to offset well pumping energy for the campus geothermal heating system, making the use of geothermal energy for campus heating 100% renewable.

The City of Klamath Falls constructed a geothermal district heating system in 1981, and has operated it since. As of its 25th anniversary in 2006, the system served 24 buildings totaling about 400,000 sq. ft., 150,000 sq. ft of greenhouse space (IFA nurseries), about 105,000 sq. ft. of sidewalk snowmelt systems (including the Wall Street bridge) and process heating at the Klamath Falls wastewater treatment plant (WWTP) (Brown, 2007). One of the customers of the district heating system is the Klamath Basin Brewing Company, which is the only known use of geothermal energy in the world for beer brewing. The district heating system was expanded to include the as yet undeveloped "Timbermill Shores Development" on a former timber mill site, which includes an additional 120,000 sq. ft of sidewalk snow-melting and capacity for about 330,000 sq. ft of building floor space (Travis, 2011). The city recently (2010-2011) added the TImbermill Shores snow-melting areas to the district heating system, in addition to about 1,500 sq. ft at Veterans Park, bring the total snow-melted area handled by the geothermal district heating system to about 246,500 sq. ft (Travis, 2011). Customers who connect to the district heating system are charged for thermal energy at a discounted rate relative to the prevailing natural gas cost. At 2011 natural gas costs, district heating customers save over $100,000 combined in energy costs annually.

Six Klamath Falls schools (Klamath Union High (location of Big Springs), Mazama High School, Roosevelt Elementary Ponderosa Jr. High, Mills Elementary and Klamath Institute) use geothermal energy for space heating, hot water generating, and some snow melting. Lund and Lund (2010) describe geothermal energy use at three of these schools in detail. Ponderosa Middle School boasts the largest capacity downhole exchanger system in Klamath Falls. At 2011 natural gas prices, the City of Klamath Falls schools save about $300,000 per year in energy costs.

Figure 9. Tree seedlings grown in IFA greenhouses heated by the Klamath Falls district geothermal heating system.

Sky Lakes Medical Center in Klamath Falls (formerly Merle West Medical Center) is another old, very large user of geothermal energy. The building was originally constructed in 1964, with the geothermal heating system installed as a retrofit in 1976. The geothermal source is the same aquifer as that used by OIT and the 550 or so individual wells in town. The geothermal heating system was designed to provide space heat and domestic hot water to the 96,000-sq. ft main building; a 56,000-sq.-ft addition; an adjacent 56,000-sq. ft nursing home and snow melting for the main entrance area. Since that time, the approximate areas heated have grown to include 300,000-sq. ft main building; and a 45,000 sq. ft medical office building (Geo-Heat Center, 2003b). A new 100,000 sq ft addition was completed in 2007, in addition to a 1,500 sq. ft geothermally snow-melted helicopter pad.

The City of Klamath Falls also consists of a number of commercial and institutional buildings

that use geothermal energy for space heating, such as: the so-called Vandenberg Road Complex (which houses Klamath County Jail, County Sheriff's Offices, Mental Health Building, Juvenile Detention and County Extension office), Herald and News (local newspaper), REACH, Inc. Juniper Processing, Klamath County Maintenance Shop, Klamath Falls YMCA, approximately 13 apartment buildings, and approximately 5 churches. Four public and private swimming pools in Klamath Falls are also heated with geothermal energy: OIT pool, Ella Redkey swimming pool (which uses a downhole heat exchanger), Klamath Union High School pool and the Klamath Falls YMCA pool. Additional geothermal snow-melting installations include a 442.5 feet long and 53.5 feet wide railway bridge underpass near downtown Klamath Falls, and driveway approaches to the Herald and News Building.

Figure 10. Photo of the Medo-Bel Creamery in the 1970s (source: Geo-Heat Center Archives).

There are also a number of historical uses of geothermal energy in Klamath Falls that are no longer operational. For example, a bathhouse was constructed in 1928, known locally as Butler's Natatorium where both swimming and bathing were available. Geothermal water was also used to heat the White Pelican Hotel in 1911, but unfortunately, the hotel burned in 1926 and was replaced with the Balsiger Motor Company building, remnants of which still stand today. The Medo-Bel Creamery (formerly the Lost River Dairy) used geothermal energy for space heating and milk pasteurization.

Geothermal energy utilization in Klamath County is not limited to Klamath Falls. The Klamath Hills area, located between Klamath Falls and the Oregon-California border is home to the Liskey Ranch, which has seen a wide range of geothermal applications since the 1970s. Groundwater temperatures available for utilization are on the order of 190 to 210˚F, and wells on the property can produce geothermal water at several hundreds of gallons per minute. Current uses of geothermal energy associated with the Liskey Ranch include space heating, greenhouse heating, and aquaculture pond heating. Greenfuels of Oregon, a biodiesel company, at one time operated in one of the Liskey greenhouses, but shut down recently. The greenhouses are now leased to two different companies (Riley, 2010); Fresh Green Organics, a community supported agriculture (CSA) organization that grows a wide array of produce, and Biotactics, a bio-controls company that raises spider mites and predator mites with the use of lima bean crops. "Gone Fishing", an aquaculture operation owned by biologist Ron Barnes, started in 1990 using the effluent from a geothermal greenhouse operation on the Liskey Ranch. In the past, the operation consisted of 37 ponds located on the Liskey Ranch and he has since expanded to 35 across the highway, which are used to raise 85 varieties of tropical fish (cichlids) that originated from Lake Malawi in East Africa's Great Rift Valley and from Central America. Today, due to economic reasons, Mr. Barnes raises tilapia for sale to local markets.

A case study of this aquaculture operation conducted by the Geo-Heat Center in 2003

estimated that about $1.35 million was saved in annual energy costs (Geo-Heat Center, 2003a).

Figure 11. Photo of aquaculture ponds near Liskey Ranch.

Other sporadic uses of geothermal energy have been identified in Klamath County, such as home heating in Olene and near Bonanza. Several undeveloped springs exist in the Olene area, and it is unsure whether the three geothermal areas in Klamath County (Klamath Falls, Olene Gap and Klamath Hills) are supplied by the same geothermal source, or whether they result from separate circulation patterns along faults (Lineau, 1989). The Olene area has recently (2011) been the subject of intense geothermal exploration.

Lake County: The Town of Lakeview has long experience using local geothermal resources, with wells capable of supplying water at temperatures up to 205°F. The range of geothermal applications includes a commercial greenhouse operation, space heating at a hotel, home heating, and uses at the Oregon Department of Corrections Warner Creek Facility. Additional geothermal resources exist in the north and south areas of Lakeview's Urban Growth Boundary and the Town of Lakeview is currently working on developing these resources for power generation and district heating.

"Old Perpetual" is the name to Lakeview's famous Geyser, located at Hunter's Resort just North of Lakeview. This geyser was created by the accidental drilling of a water well that tapped the geothermal water, and ever since, a geyser of boiling water is produced nearly every minute. The original building at Hunter's Hot Springs was constructed in 1925, and represented the formation of the Hunters Chlorine Hot Springs Club for the purpose providing therapy, rest and recuperation. Shortly thereafter, the facility became a medical clinic, offering hot baths and medical treatments and a restaurant. The property sold in 1943 to private interests who further developed additional rooms and a lounge. Since then, it has operated as the Motel and Hot Springs, with heating for the facilities being provided by a direct hook up to the geyser spring.

Figure 12. Hunter's Hot Springs Hotel in Lakeview.

According to Sifford (2010), wildcat exploration for high-temperature resources occurred first in 1959 with the arrival of Magma Power. Magma affiliate Nevada Thermal drilled a 1684-ft deep well in the Warner Valley near Adel, that reportedly flowed 250°F water. The well began geysering, and has since been known as Crump Geyser. In 1960, Magma drilled a 510-ft deep well just north of Lakeview that flowed 217°F water, and that well was subsequently put to use heating a greenhouse.

Wildcat generation occurred in March 1982 when a 40kW Solar Power Systems binary plant operated briefly at the Rockford Ranch well in Lakeview (Sifford, 2010). Pacific Power & Light (PP&L) bought the power output to attempt to demonstrate plant technical feasibility using 176°F water, but results were largely negative. Later in 1982, three 400 kW Solar Power System binary generators were installed in the Hammersly Canyon area north of Lakeview, operating with 212°F water, which was later augmented with three 300 kW Ormat binary generators in April 1983. PP&L again contracted to purchase the power to demonstrate plant technical feasibility starting in March 1984, but no significant operation ever took place, mostly as a result of difficulties in securing a long term power sales agreement, cooling operation, and interference with nearby wells (Sifford, 2010). While this plant only operated for about 12 months, it represented a milestone in geothermal power generation in Oregon that was not surpassed until over 25 years later, when the first permanent geothermal power plant was installed on OIT's campus in 2010.

Summer Lake is a KGRA, and consists of a number of direct uses, mainly hot springs resorts and an aquaculture operation, Desert Springs Trout Farm. Summer Lake Hot Springs consists of four natural hot springs: one that produces approximately 113°F water at 25 gallons per minute serving as the source for a 15-ft by 30-ft pool, and three others that generate water at 106 to 118°F, and serve the various houses, cabins, and facilities on the property. Prior to the arrival of early settlers', the undeveloped springs were known as "Medicine Springs" to Native Americans. In 1843, explorer John Fremont (the man credited with naming Summer Lake, due to the area's warm climate) once praised the water's healing properties as the best he'd come across.

High Lava Plains: The High Lava Plains extend from the foot of the Cascade Mountains to the eastern border of the Harney Basin. This region is an uplifted area of young lava flows marked with surface volcanic features such as cinder cones, craters, and lava buttes. Overall, the area is the youngest and least eroded areas in Oregon. Newberry Crater, a broad shield volcano with a summit caldera containing two large lakes and hot springs is a prominent feature on the landscape. Numerous hot springs and wells in the Harney Basin, in association with young volcanic features, give indications of the geothermal resources of this area.

The USGS has identified two KGRAs: Newberry Crater and Burns Butte. The only sizeable communities in this area are Bend and Burns.

Figure 13. Crystal Crane Hot Springs near Crane, OR.

Harney County: The Crane area is home to rustic Crystal Crane Hot Springs that offers cabin accommodations and soaking pools fed by geothermal spring water. Neighboring the Hot Springs is an abandoned greenhouse that, until recently, was heated with a geothermal well.

Jefferson County: Kah-Nee-Ta High Desert Resort & Casino is located on the eastern flank of the Cascades, at the beginning of the high desert region of Central Oregon, just two hours from Portland and an hour and a half from Bend. The Kah-Nee-Ta swimming pool is located on the 600,000-acre Confederated Tribes of Warm Spring Reservation, formed in 1879 and settled by Paiutes, Warm Springs and Wasco tribes. The swimming pool is located adjacent to the Warm Springs River, a tributary of the Deschutes River. The resort was started in the early 1960s, and in addition to the swimming pool includes a lodge, an RV village with condos and tepees, and a gambling casino (Lund, 2004). Warm Springs in this area have been used by the local Indians for centuries, and today, produce about 400 gallons of water per minute at 128^{o}F and are used to heat the swimming pool. None of the other facilities on the resort/casino area are heated by geothermal energy due to the distance and limitation on the flow rate from the springs (Lund, 2004).

Figure 14. Kah-Nee-Ta swimming pool (source: Lund, 2004).

Western Snake River Plain: The Western Snake River Plain (Owyhee Uplands) in east central Oregon is part of a large trough extending from Wyoming across Idaho and into Oregon, with topography similar to the Basin and Range Province. The USGS has designated a large area around the town of Vale as a KGRA. This area coincidentally is also a rich agricultural area, so there is potential for direct geothermal uses related to food processing.

Malheur County: Vale hot springs, near the Idaho border was a stop for early settlers on the Oregon Trail. Until recently, a mushroom plant used those same 207°F waters in its operation for process heating and absorption cooling. The facility closed for unknown reasons. Seasonal agricultural processing and modest space heating applications exist.

Northeastern Oregon: This area is made up of separate, so-called "exotic terranes," and at-one-time volcanic island chains that were amalgamated to the North America continent as it moved westward toward the Pacific. Fossils found in this province reveal their foreign origins. Placer and lode gold mines were active here in the past, and towns such as John Day and Baker City, together with the Sumpter gold dredge, are reminders of the gold mining heritage of the Blue Mountains.

There are no KGRAs in this region, but the area is widely recognized as having significant low-temperature resource potential, particularly in the La Grande area.

Union County: La Grande has warm water within its city limits. Hot Lake, about 10 miles east of La Grande, has an interesting geological, pioneer, and medicinal history. The 2½ million gallons of hot 186ºF water that flow out of the ground every day have always been a natural attraction for travelers in the Grand Ronde Valley. Native American tribes used its "curative powers" and set it aside as a peace ground. The Hot Lake area was used for rest and healing of their sick and wounded, and as a summer rendezvous area. Hot Lake was first seen by European settlers on August 7, 1812. The Wilson Price Hunt

expedition was traveling from what is now Astoria, Oregon, to St. Louis, Missouri, and noticed the hot spring. Eagles Hot Lake RV Park offers accommodations for campers and large RVs with a heated pool and spa.

Figure 15. Hot Lake poster (source: itooned.com)

Hot Lake Springs Bed & Breakfast, just south of La Grande, has undergone restoration after fire destroyed half of the building in 1934, and several owners tried to restore the property over the years but failed to gain community support and none were successful. The building was abandoned, looted, and ready to fall in on itself when the Manuel family began restoring Hot Lake Springs in 2003. The renovated facility opened in 2010.

The community of Cove also makes use of geothermal resources at the Cove Swimming Pool, a historic landmark in Eastern Oregon. Geothermal springs have warmed the Cove pool continuously for more than 75 years, which has operated throughout its existence as a private business. The springs are gathered in a concrete pool, providing nearly perfect 86F water. The 60 ft x 65 ft pool is constantly refreshed by the flow of mineral water at a rate of 110 gallons per minute.

Grant County: Blue Mountain Hot Springs has had a vibrant past. Geothermal water issues from the springs at 120º F, but cools to about 100^{o}F as it flows into a swimming pool. The springs have been frequented for as far back as history is recorded for the area. The first documented settlement of the springs was by a furniture maker and his wife in the 1860s. As the decades past, the springs became known as a destination for viewing the mystery of geothermal activity, seeking wellness from the mineral rich water, drinking, swimming, and bathing. At one time under private ownership, today the hot springs are a scenic destination open to outside guests.

Ritter Hot Springs is a historic overnight stop on the old stagecoach road between Pendleton and John Day. The hot springs issue from the ground at 106^{o}F, and water is piped across the Middle Fork of the John Day River to a swimming pool, which averages 85^{o}F. The facility is open seasonally.

Umatilla County: Lehman Hot Springs, located west of La Grande, is one of the largest hot springs in the Northwest. The springs were formerly a gathering place for the Nez Perce Indians. A 9,000 foot square swimming pool on the property has temperatures ranging from 88 to 106^{o}F. Lehman offers numerous amenities, including soaking pools, activities, and lodging.

Northeastern Oregon was also home to the now-closed Bar M Ranch (Umatilla County), Medical Hot Springs (Union County), and Radium Hot Springs (Baker County), which hail from the historical era of major fashionable hot springs resorts, of which Oregon had several. Medical Hot Springs and Radium Hot Springs opened around the turn of the 20th century, and remnants of the original facilities exist with the hopes of rejuvenating them someday. The Bar M

Ranch at Bingham Hot Springs, built in 1864 as a stage coach stop during the Civil War era, recently closed and is for sale.

The numerous geothermal-related businesses across Oregon employ many people directly and indirectly. Geothermal heating systems are generally low-maintenance, and therefore employ only a few folks that are qualified to work on them. However, space heating of buildings and other applications using geothermal energy for heat results in significant energy cost savings to people, which, in turn, results in money that can be kept in the local economy. Relative to 2011 natural gas prices, an estimated $9 million is saved annually by Oregonians using geothermal energy, representing dollars that can stay in the local economy. The use of geothermal energy that directly employs the most people in Oregon is by far the resort and spa industry. Mineral spas and resorts, and greenhouses and aquaculture operations simply would not exist where they are in Oregon without the geothermal resource. Using a standard multiplier of 2.5, geothermal businesses create an estimated 300 direct, indirect, and induced jobs in Oregon.

Environmental benefits

In addition to energy savings, geothermal energy usage prevents the emissions of greenhouse gases (GHG) and air pollutants, helping to keep a healthy living environment. If these businesses and residences used fossil fuels to generate the heat that geothermal water provides, they would emit at least 156,000 tonnes of carbon dioxide equivalent each year (Table 1) — the equivalent of removing 30,500 passenger vehicles from the road, saving 362,800 barrels of oil, and saving 33,200 acres of pine forest.

There are additional environmental benefits of geothermal snow-melting through the avoidance of de-icing salts and other chemicals that ultimately enter lakes, and may have negative impacts on fish and plants. Geothermal snow-melting projects in Oregon combine to avoid hundreds of pounds of de-icing salts annually from entering Oregon's streams, rivers, and lakes.

Social benefits

Social benefits are difficult to measure quantitatively. One key social benefit from geothermal energy use in Oregon, however, is improved quality of life through recreation and spa therapy. District energy systems are known to promote and foster community pride. Geothermal sources provide many unique recreational opportunities enjoyed by tens of thousands of people each year, attracting tourists to the state. Given the rich history of the geothermal spa industry, social benefits have been evident for many past generations.

The future

Oregon has significant geothermal potential for future uses, from new and expanding applications of direct use heating, to resurgence in mineral spa therapy, to development of low-to-moderate temperature resources for electrical power generation.

According to Boyd (2007), only about 1.4% of Oregon's feasibly accessible geothermal resources are being tapped. Boyd (2007) identified about 35 sites in Oregon that are suitable for potential geothermal power generation, 5 of which are currently at some stage in development at the time of this report: OIT Campus Plant #2 (Klamath Falls), Newberry volcano, Crump Geyser, Neal Hot Springs, and

Paisley. These current developments alone could have as much potential as 200 MWe (Sifford, 2010).

Boyd (2007) also identified about 32 communities in Oregon that are collocated with geothermal resources. These communities have resource temperatures greater than 122^{o}F, located within 5 miles of the community.

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Disclaimer

Table 1. Energy Production and Carbon Emissions Offsets by Geothermal Energy Utilization in Oregon.

Site	Location	Application	Temp.	Annual Energy Use		Annual Emission Offsets (metric tonnes)**		
			(F)	(10^9 Btu/yr)	(10^6 kWh)	NO_x	SO_x	CO_2
"Gone Fishing" (Liskey Ranch)	Klamath County	Aquaculture	180	28	8.2	13	13	7,597
"Gone Fishing" (Liskey Ranch)	Klamath County	Aquaculture	180	28	8.2	13	13	7,597
Summer Lake Aquaculture	Summer Lake	Aquaculture	NA	28	8.2	13	13	7,597
City of Klamath Falls	Klamath Falls	District Heating	210	35	10.3	16	17	9,497
Oregon Institute of Technology (OIT)	Klamath Falls	District Heating	192	54.8	16.1	24.9	26.3	14,881
Cove Hot Spring	Union County	Greenhouse	108	1.4	0.4	0.6	0.7	380
Jackson Greenhouses	Ashland	Greenhouse	111	0.5	0.1	0.2	0.2	136
Liskey Greenhouses	Klamath County	Greenhouse	199	15.5	4.5	7.0	7.4	4,206
The Greenhouse	Lakeview	Greenhouse	220	12.4	3.6	5.6	6.0	3,364
Aq Dryers	Vale	Agriculture	200	6.5	1.9	3.0	3.1	1,764
City of Klamath Falls District Heating	Klamath Falls	Snow-Melting	125	49.3	14.4	22.4	23.7	13,377
Herald and News	Klamath Falls	Snow-Melting	>212	1	0.3	0.5	0.5	271
Highway De-icing	Klamath Falls	Snow-Melting	190	6	1.8	2.7	2.9	1,628
Oregon Institute of Technology (OIT)	Klamath Falls	Snow-Melting	150	8	2.3	3.6	3.8	2,171

**Emission factors from Lund et al. (2010).

Table 1 (*CONTINUED*). Energy Production and Carbon Emissions Offsets by Geothermal Energy Utilization in Oregon.

Site	Location	Application	Temp.	Annual Energy Use		Annual Emission Offsets (metric tonnes)**		
			(F)	(10^9 Btu/yr)	(10^6 kWh)	NO_x	SO_x	CO_2
Austin Hot Springs	Clackamas County	Resort/Pool	186	1	0.3	0.5	0.5	271
Bagby Hot Springs	Clackamas County	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Belknap Hot Springs	Lane	Resort/Pool	160	5.5	1.6	2.5	2.6	1,492
Blue Mountain H.S. Guest Ranch	Prairie City	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Breitenbush Community	Detroit	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Cove Swimming Pool	Cove	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Crystal Crane Hot Springs	Burns	Resort/Pool	185	7	2.1	3.2	3.4	1,899
Hunter's Lodge	Lakeview	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Hot Lake Resort	La Grande	Resort/Pool	208	7	2.1	3.2	3.4	1,899
J Bar L Guest Ranch	Canyon City	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Jackson Hot Springs	Ashland	Resort/Pool	100	7	2.1	3.2	3.4	1,899
Klamath Falls Swimming Pools (5)	Klamath Falls	Resort/Pool	180	4.3	1.3	2.0	2.1	1,167
Lehman Hot Springs	Ukiah	Resort/Pool	167	7	2.1	3.2	3.4	1,899
Public Swimming Pool	Lakeview	Resort/Pool	180	1.8	0.5	0.8	0.9	488
Ritter Hot Springs	Ritter	Resort/Pool	NA	7	2.1	3.2	3.4	1,899
Summer Lake Hot Springs	Summer Lake	Resort/Pool	118	7	2.1	3.2	3.4	1,899
Kah-nee-ta	Warm Springs	Resort/Pool	126	27.6	8.1	12.5	13.3	7,489

**Emission factors from Lund et al. (2010).

Table 1 (*CONTINUED*). Energy Production and Carbon Emissions Offsets by Geothermal Energy Utilization in Oregon.

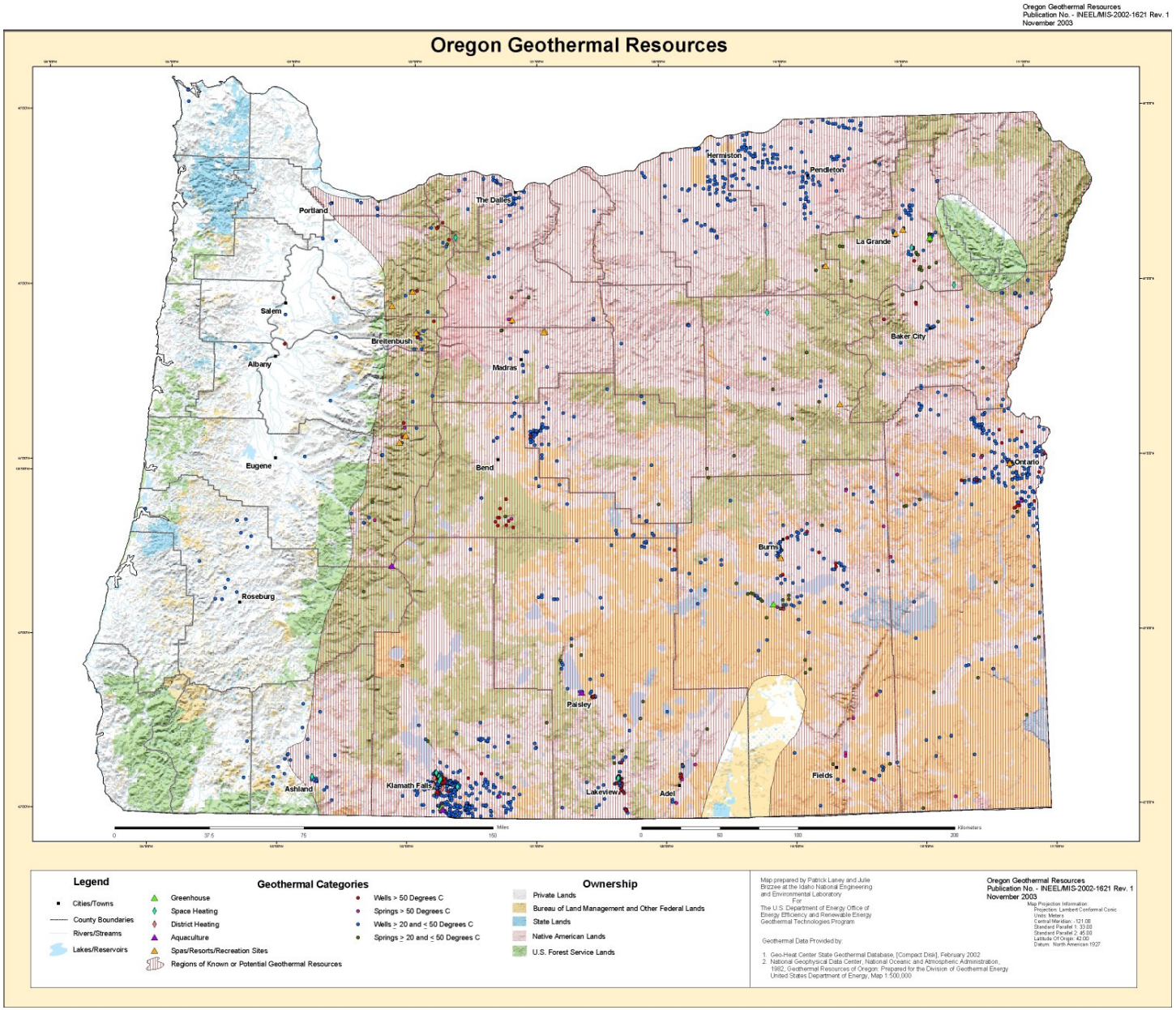
Site	Location	Application	Temp.	Annual Energy Use		Annual Emission Offsets (metric tonnes)**		
			(F)	(10^9 Btu/yr)	(10^6 kWh)	NO_x	SO_x	CO_2
Baker Swimming Pool	Baker	Resort/Pool	75	1.8	0.5	0.8	0.9	488
Hunters Hot Spring	Lakeview	Space Htg.	202	1.7	0.5	0.8	0.8	461
Klamath Falls Apartment Bldgs. (13)	Klamath Falls	Space Htg.	180	14.2	4.2	6.5	6.8	3,853
Klamath Falls Churches (5)	Klamath Falls	Space Htg.	190	3.9	1.1	1.8	1.9	1,058
Klamath Co. Shops	Klamath County	Space Htg.	118	3.6	1.1	1.6	1.7	977
Klamath County Jail	Klamath Falls	Space Htg.	180	23	6.7	10.5	11.0	6,241
Lakeview Residences (9)	Lakeview	Space Htg.	190	0.9	0.3	0.4	0.4	244
Langel Valley	Bonanza	Space Htg.	147	0.1	0.0	0.0	0.0	27
Maywood Industries of Oregon	Klamath County	Space Htg.	118	6.8	2.0	3.1	3.3	1,845
Sky Lakes Medical Center	Klamath Falls	Space Htg.	191	23.9	7.0	10.9	11.5	6,485
Crystal Terrace Retirement Community	Klamath Falls	Space Htg.	184	6	1.8	2.7	2.9	1,628
Olene Gap	Klamath County	Space Htg.	189	0.1	0.0	0.0	0.0	27
Vale Residences	Vale	Space Htg.	185	0.7	0.2	0.3	0.3	190
Vale Slaughter House	Vale	Space Htg.	150	0.7	0.2	0.3	0.3	190

**Emission factors from Lund et al. (2010).

Table 1 (*CONTINUED*). Energy Production and Carbon Emissions Offsets by Geothermal Energy Utilization in Oregon.

Site	Location	Application	Temp.	Annual Energy Use		Annual Emission Offsets (metric tonnes)**		
			(F)	(10^9 Btu/yr)	(10^6 kWh)	NO_x	SO_x	CO_2
Summer Lake Hot Springs	Lake County	Space Htg.	109	2.5	0.7	1.1	1.2	678
Klamath Falls Residence (550)	Klamath Falls	Space Htg.	180	95.5	28.0	43.4	45.9	25,912
Klamath Falls Schools (6)	Klamath Falls	Space Htg.	180	19.8	5.8	9.0	9.5	5,372
Henley High School	Klamath Falls	Space Htg.	127	6.6	1.9	3.0	3.2	1,791
Herald and News	Klamath Falls	Space Htg.	>212	3	0.9	1.4	1.4	814
Breitenbush Hot Springs	Marion County	Space Htg.	212	3.9	1.1	1.8	1.9	1,058
Hot Lake RV Park	Union County	Space Htg.	190	1.8	0.5	0.8	0.9	488
Jackson Hot Springs	Ashland	Space Htg.	111	4.4	1.3	2.0	2.1	1,194
Medical Hot Springs	Union County	Space Htg.	140	1.1	0.3	0.5	0.5	298
Radium Hot Springs	Union	Space Htg.	136	3.6	1.1	1.6	1.7	977
YMCA	Klamath Falls	Space Htg.	147	3.1	0.9	1.4	1.5	841
TOTALS				**575**	**169**	**262**	**276**	**156,108**

**Emission factors from Lund et al. (2010).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Portland
Salem
Albany
Eugene
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Pendleton
La Grande
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Ontario
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Legend
Cities/Towns
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Rivers/Streams
Lakes/Reservoirs
Geothermal Categories
Greenhouse
Space Heating
District Heating
Aquaculture
Spas/Resorts/Recreation Sites
Regions of Known or Potential Geothermal Resources
Wells > 50 Degrees C
Springs > 50 Degrees C
Wells > 20 and ≤ 50 Degrees C
Springs > 20 and ≤ 50 Degrees C
Ownership
Private Lands
Bureau of Land Management and Other Federal Lands
State Lands
Native American Lands
U.S. Forest Service Lands
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Geothermal Data Provided by:
1. Geo-Heat Center State Geothermal Database, [Compact Disk], February 2002
2. National Geophysical Data Center, National Oceanic and Atmospheric Administration, 1982, Geothermal Resources of Oregon: Prepared for the Division of Geothermal Energy United States Department of Energy, Map 1:500,000
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Map Projection Information:
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Central Meridian: -121.00
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