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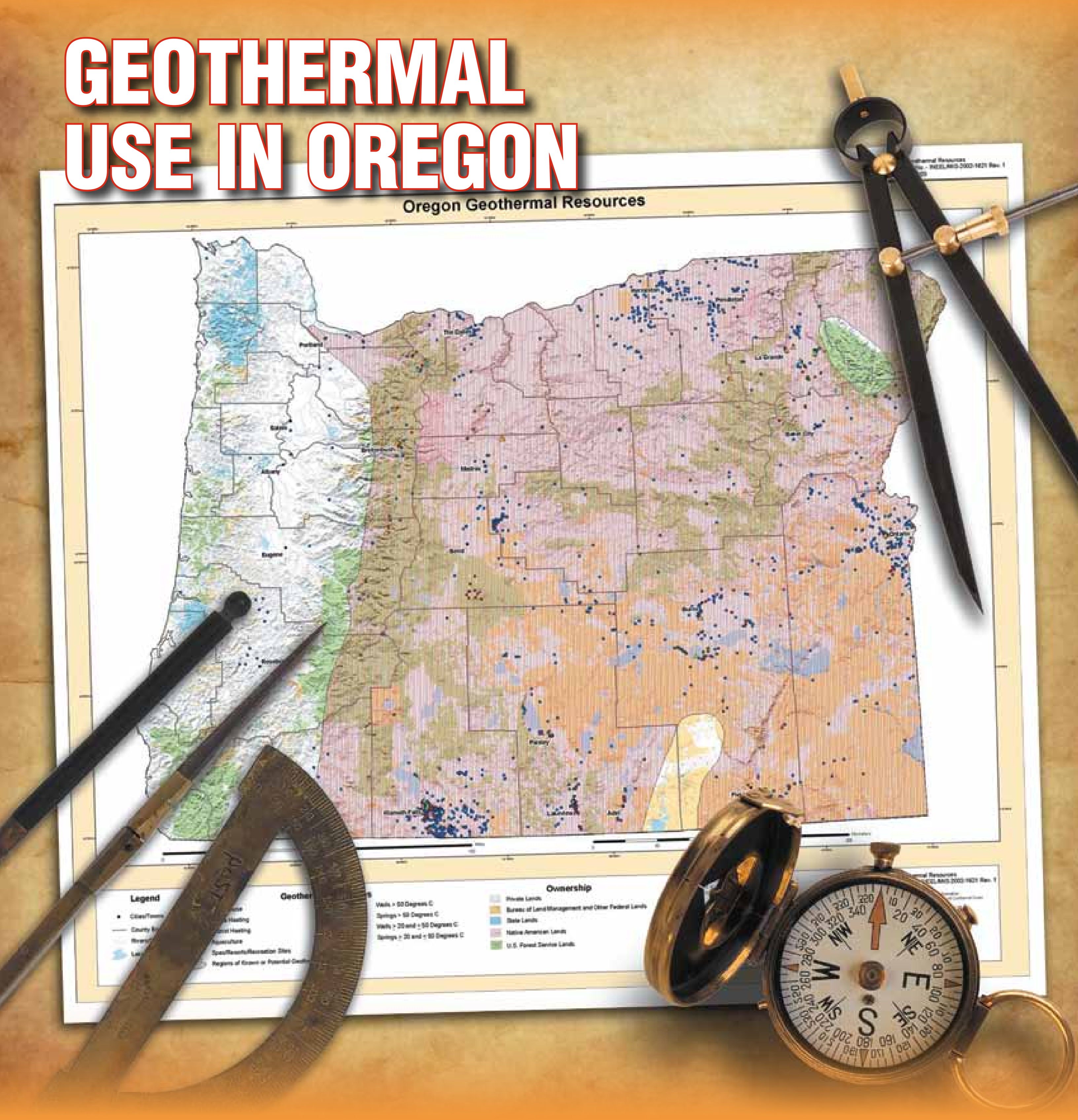
GEO-HEAT CENTER QUARTERLY BULLETIN

GEOTHERMAL USE IN OREGON



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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

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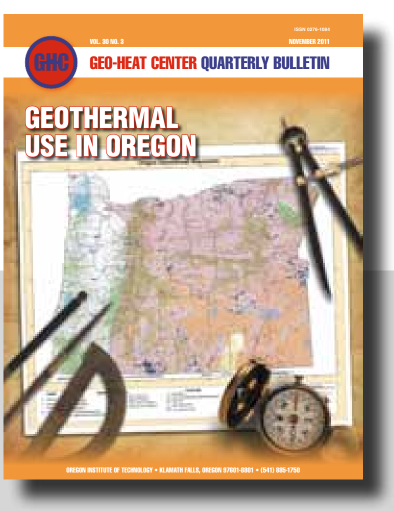

Cover: Map of Oregon Geothermal Resources.

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THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL BENEFITS OF GEOTHERMAL USE IN OREGON

Andrew Chiasson, Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, Oregon

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.

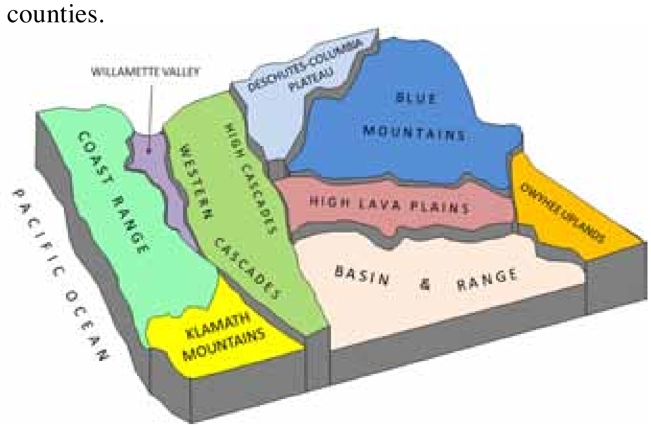

Figure 1. Physiographic regions of Oregon (reproduced from graphic by Elizabeth L. Orr, Geology of Oregon).

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).

Figure 2. Map of Oregon Counties.

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°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°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 known 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.

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.

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

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

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.

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

Figure 10. Photo of the Medo-Bel Creamery in the 1970s.

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 biocontrols 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).

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.

Figure 11. Photo of aquaculture ponds near Liskey Ranch.

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.

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

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

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, Oregon.

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°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.

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.

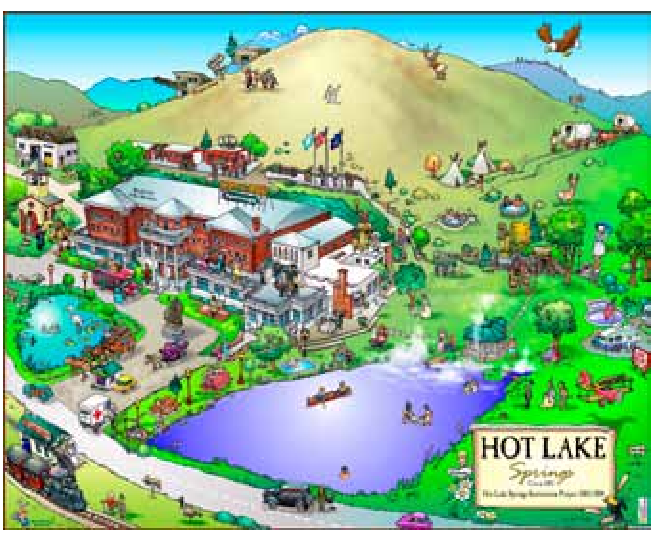

Figure 15. Hot Lake poster (source: itooned.com)

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 86˚F 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 120˚F, but cools to about 100˚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˚F, and water is piped across the Middle Fork of the John Day River to a swimming pool, which averages 85˚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˚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

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

Site	Location	Application	Temp (F)	Annual Energy Use		Annual Emssion Offsets (metric Tonnes)*		
				(10^9 Btu/yr)	(10^6 kWh)	NOx	SOx	CO_2
"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
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

Site	Location	Application	Temp (F)	Annual Energy Use		Annual Emssion Offsets (metric Tonnes)*		
				(10^9 Btu/yr)	(10^6 kWh)	NOx	SOx	CO_2
Kah-nee-ta	Warm Springs	Resort/Pool	126	27.6	8.1	12.5	13.3	7,489
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
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).*

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, five 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°F, located within 5 miles of the community.

ACKNOWLEDGEMENTS

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DISCLAIMER

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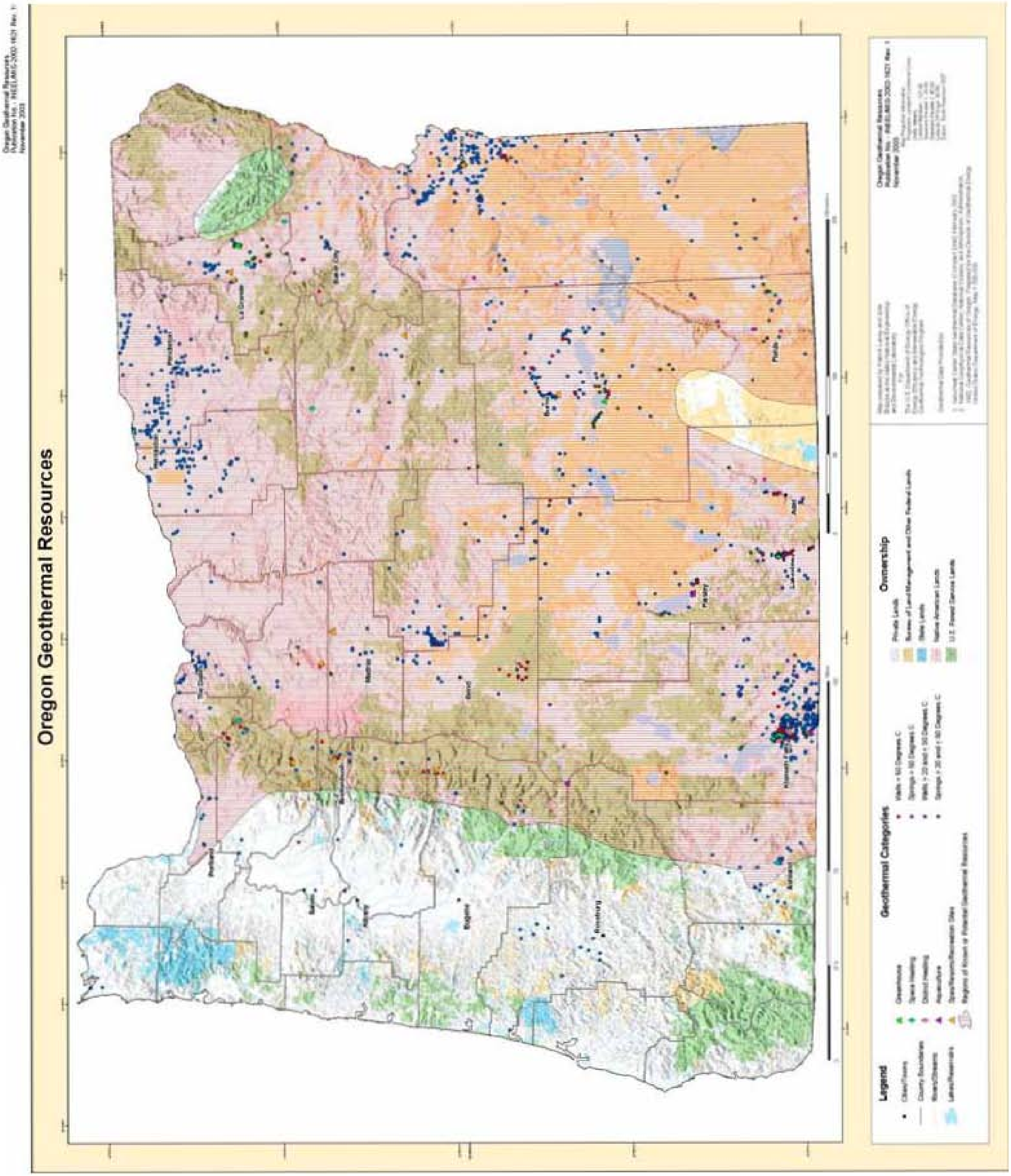
Oregon Geothermal Resources
Legend
Geothermal Categories
Ownership

GEOTHERMAL HEAT IN AGRICULTURE: PRELIMINARY RESULTS OF AN ENERGY INTENSIVE SYSTEM IN ICELAND

Robert Dell, C.S. Wei, George Sidebotham, Vito Guido, Joseph Cataldo, Kelly Smolar, Alexander Bronfman, The Cooper Union, New York, New York, USA; Rúnar Unnþórsson, Magnus Thor Jonsson, University of Iceland, Reykjavík, Iceland; Tryggvi Þórðarson, The Environmental Agency of Iceland

EDITOR'S NOTE

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ABSTRACT

A new energy intensive outdoor shallow system of geothermal heated ground agriculture was constructed and has been tested at the Agricultural University of Iceland in Hveragerdi since 2007. The 5 by 10 square meter experimental heated garden and a 5 by 5 square meter control garden both have three different soil mixtures and depths of 10 and 20 centimeters (cm) over a piping system that is analogous to a heated sidewalk. A geothermal borehole supplies steam and steam condensate at temperatures from 100°-125°C. A traditional shell and tube heat exchanger circulates a mixture of water and automotive anti-freeze continuously throughout the year in a closed loop at temperatures between 45-65°C. Soil temperatures at 10 cm depth range from 25-40°C. A similar system in New York City is incorporated into green roofs. Both heated bed systems have extended growing seasons and an average seasonal increase in plant growth of 20%. In Iceland out of range cultivars grow in the heated beds and either die or grow poorly in the control plot. Some heated grass areas are green throughout the winter. In New York City early and enhanced tomato harvests and winter flowers have been documented. In both plots weed growth patterns produced similar results. These preliminary results warrant further study. The growing season was increased both in Iceland and New York City by a minimum of four weeks.

INTRODUCTION

The trend in the geothermal energy industry is to extract 160-350°C steam from bore holes in high temperature areas. The waste heat left after electricity production still has a temperature of up to 130-160°C. In Iceland most of this waste heat can be applied toward cascaded utilization in district heating and the heating of greenhouses. Swimming pools and spas can also use part of this energy. The planned electrical power plants in Iceland will produce substantially more of this low temperature energy than the projected demands.

Geothermal heated swimming pools are very common in Iceland. Geothermal heated greenhouses are still common in locations such as Hveragerdi. Many of the older style greenhouse operations are being abandoned. This may be caused by higher costs of energy, materials, and labor. However, there appear to be some new efforts to revitalize this industry.

Another common cascaded utilization of geothermal energy in Iceland is the heating of sidewalks and streets. The basic engineering data used to construct these systems is based upon American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) specifications for heated sidewalks (ASHRAE, 1999), which is used as the basis for Iceland's heated sidewalks.

In Iceland there have been trials with the outdoor heating of soil (bottom heat) for agricultural purposes. A few existing outdoor heated ground agricultural systems have pipes that are about 40-80 centimeters below the surface and up to a meter apart. These approaches create minimal soil heating in the range of 6-12°C. They were heated for only a few months in the spring. There is additional current research toward the use of geothermal energy to heat golf course greens and athletic fields to extent the playing season.

We have developed and have been testing in Iceland since 2007 a more energy intensive shallow system of heated ground agriculture that is analogous to a heated sidewalk. In New York City, Consolidated Edison's district heating steam has no recirculation system. The waste heat, in the form of hot water or steam condensate is mixed with and cooled by the municipal water supply, thus wasting both energy and potable water. Since 2006, The Laboratory for Energy Reclamation and Innovation has been developing a system to use this thermal pollution to heat the soil of green roofs. As the waste level is decreased, less potable water is needed to cool the waste steam condensate, thereby preserving this resource for other purposes.

MATERIALS AND METHODS

Heating System

In Hveragerdi, a geothermal bore hole supplies steam and steam condensate at temperatures from 100 to 125°C. It is piped to a traditional shell and tube heat exchanger, manufactured in Iceland, which has a pump to circulate a mixture of water and automotive anti-freeze continuously throughout the year in a closed loop at temperatures between 45°C in the summer and 65°C in the winter. It has standard gate valves to control the flow. A Danfoss AVTB T self-acting temperature controller automatically controls the flow rate of the steam and steam condensate that reheats the hot water. A dial thermometer and pressure gage manufactured by Flexcon is mounted on the top of the heat exchanger to determine the water out temperature. A Rexotherm KL 2,0 dial thermometer with a temperature range of 0-120°C, was connected to the retour just above the flow meter. The Brook Crompton Parkinson KP6736 1-HP hot water circulator pump creates a flow rate of 10 liters per minute as measured by a Blue-White F-410N 1-inch NPT vertical float type flow meter.

The heat exchanger, shown in Figure 1 is 1.5 meters higher in elevation than the heated gardens; a simple semi sealed expansion chamber is used for surcharging the system. The working fluid is water with 20% automotive anti-freeze to prevent freezing of the hoses in the event of a system failure. The soil receives the fluid at 60-68°C in the colder months and between 40-50°C during the summer months. The winter energy consumption per square meter of heated garden is approximately 0.17kWh per square meter.

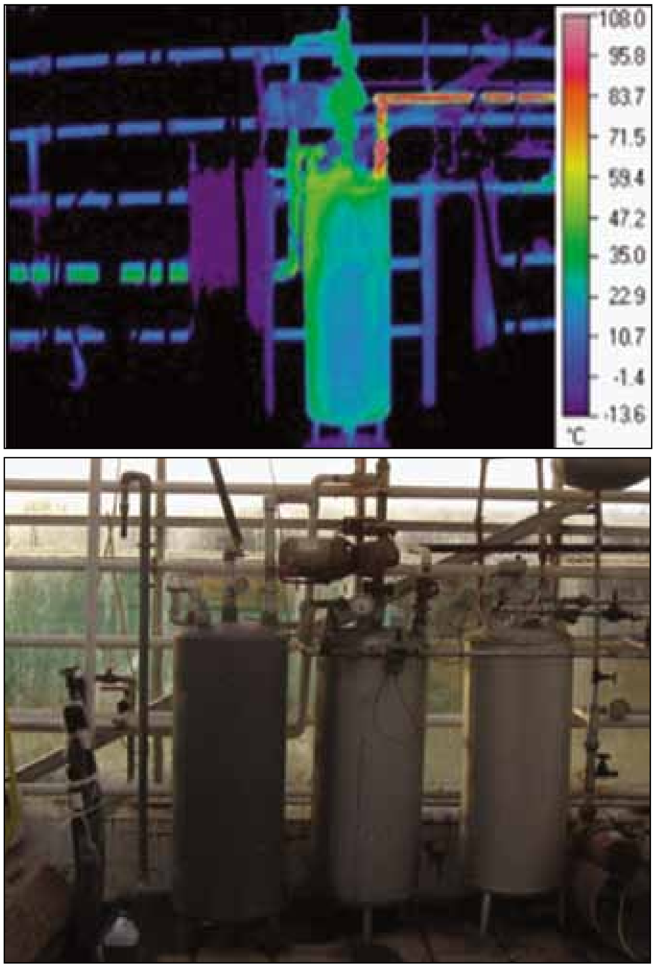

Figure 1: Mikron infrared image of the Hveragerdi heat exchanger (top), standard digital image (bottom)

Iceland Heated Garden

A 5 by 10 square meter experimental heated garden and a 5 by 5 square meter control garden were constructed, as shown in Figure 2. Both gardens were constructed, maintained, and monitored in the same manner and using the same materials, with the exception that no hot water circulates through the pipes of the control garden.

The 2.5-cm polypropylene plastic pipe, manufactured by Set Ehf in Selfoss, Iceland, was selected because of its workability, resistance to puncture and its ability to withstand several freeze-thaw cycles. Approximately 260 meters of pipe was installed in a spiral pattern to provide a more even heating profile. The plastic pipes are placed at 25 centimeters centers in the gardens. This distance is maintained by using polypropylene spacer clips manufactured by Bergplast Ehf in Hafnarfjördur. Both products are manufactured in Iceland and commonly used in heated sidewalks.

The pipes were placed on a 20-30 centimeters bed of compacted sand. They were then covered by an additional compacted sand over-layer of 4-5 centimeters. Above this layer either garden soil, peat soil or peat and sand soil were placed in the heated and the control garden at 10 and 20 centimeters depth (Figure 2). The system currently circulates the working fluid for the entire year.

Figure 2: Hveragerdi spiral piping layout (top left), sand over layer construction detail (top center), soil top layer and gravel compaction construction detail (top right), soil depths, types and location (Bottom)

Tomatoes (Lycopersicon esculentum Mill. cv. Fourth of July, cv. Bestboy and cv. Steak Sandwich) and cucumber (Cucumis sativus L. cv. Burpless) were sown on June 7 and seedlings were transplanted in 10 cm plastic pots in a heated greenhouse. Tomatoes and cucumbers were transplanted in the garden on July 1 with an average plant height of 20 centimeters for tomatoes and 10 centimeters for cucumbers. All plant selections and plant locations in the heated and control gardens were determined by using assigned numbers drawn from a hat in a double blind process. All beds were treated the same, no special watering frequencies or amounts were instituted for the heated or the unheated gardens. No fertilizers or artificial lighting were used.

New York City Heated Garden

In New York City, Consolidated Edison's municipal steam district system is analogous to the geothermal systems in Iceland. Because of the inherent problems with low temperature steam, there is no recirculation system. The waste steam and steam condensate must be cooled before it is sent to the sewer system, so it is first sent to chillers where it is cooled by the municipal potable water system, wasting both energy and water. When used to heat the growth medium of green roofs, the increased plant growth, cascade energy utilization, water savings and other benefits have great potentials. Before the heat exchanger system is finalized, tests using a conventional hot water system in a closed loop similar to what was eventually used in the Hveragerdi gardens was developed.

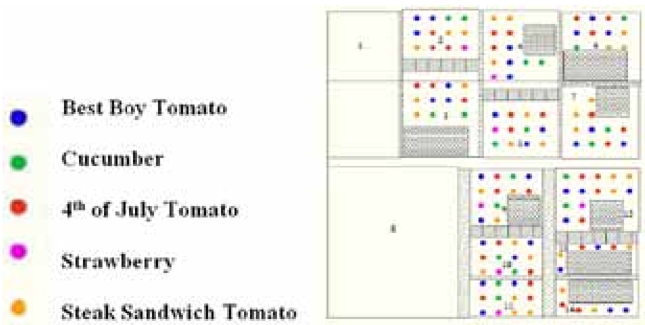

Figure 3: Crops and their locations in Hveragerdi

The first heated and control beds were built on metal frames with wheels and were 1 meter in height. The soil was contained by PVC plastic extruded tube raised exterior garden bed frames made by Pharmtec Corporation. Each bed had a 2-cm copper, PVC, and two stainless steel pipes running lengthwise that were covered with 25 centimeters of Premier Tech Ltd. PRO-MIX potting soil. The soil is 75-85% spagum peat moss with vermiculite, pearlite.

On the second story roof at the Albert E. Nerken School of Engineering at The Cooper Union, six - two square-meter green roof plots were placed on 4x8 foot ¾ inch treated plywood with 2x4 inch treated wood reinforcements on 16 inch centers, in accordance with standard United States construction practices. Four of the plots were heated, two were unheated control plots. The PVC plastic extruded tube raised exterior garden bed frames were made by Pharmtec Corporation. The tube voids were filled with 3 pound polyurethane expanding foam, manufactured by Urethane Technology Inc.

Stevens EP 60-mm reinforced TPO (thermoplastic polyolefin) single ply roofing membrane was installed, as per green roof specifications (see Figure 4). Above this layer, Stevens Garden Top Drain was installed, as per the manufacturer's specification. The rooftop garden hoses Nylobrade Braidreinforced PVC hose, ¾ inch inside diameter were placed on the top of the drainage membrane. The polypropylene spacer clips manufactured by Bergplast Ehf in Hafnarfjördur were also used on these gardens to maintain the same 25 centimeters distance between the pipes. This was covered by 10 centimeters of Skyland USA LLC, roofliteTM extensive mc growth medium for extensive green roofs in multicourse construction. The material is a mixture of mineral light weight aggregates and organic components that meets the German FLL-Guidelines.

The working fluid mixture, temperature, and flow rate is identical to the Hveragerdi gardens. The water is heated by a conventional electrical resistance Kenmore 32936 home 40 gallon 240 volt 30 amp hot water heater that is surcharged to 25 psig by the municipal water system. A Blue-White F-410N ½ inch NPT vertical float type flow meter and a Watts dial temperature and pressure gage monitor the hot water system. The pump is a Taco 009 bronze cartridge circulator.

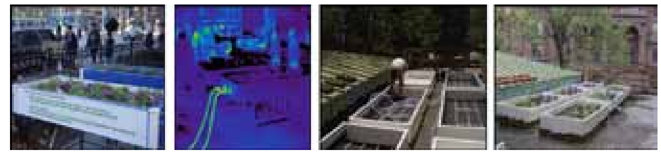

Figure 4: New York City gardens: first heated gardens; ibid infrared image; heated green roof construction detail; finished gardens.

According to ASHRAE, New York City needs 222 BTU's per square foot to keep sidewalks free of snow. Both the New York City and the Hveragerdi heated gardens consume approximately 55 BTU's per square foot, almost exactly one fourth as much heat energy.

Tomatoes (Lycopersicon esculentum Mill. cv.. Bestboy and cv. Steak Sandwich) were sown on or about April 1 and seedlings were transplanted in 10 centimeters plastic pots at D'ercole Farms, a commercial garden center, in a heated greenhouse. Tomatoes were transplanted on April 26 with an average plant height of 20 centimeters. Pansies (Viola wittrockiana cv. Atlas purple) were sown on or about October 10 in plastic trays at D'ercole Farms in a heated greenhouse. They were transplanted on December 23 with an average plant height of 20 centimeters. Randomisation and treatments were done according to Iceland.

MEASUREMENTS

Plant growth was measured by total plant height and width using Mitutoyo digital calipers and meter measuring sticks. A 4x4 cm rigid 3-mm plastic square was placed near the plant stems during measurements to serve as a level surface for plant vertical dimensions and stem diameters taken at 2 centimeters height.

In addition to the dial indicators, temperatures were measured using a variety of systems including: a Linear Labs C-1600 non contact infrared thermometer, a Fluke 867B graphical multimeter with a temperature probe, and a Mikron 7200 thermal camera. For longer term soil temperature monitoring, an Onset Computer Corporation Hobo Water Temp Pro v2 Data Logger system was used in Hveragerdi and an Omega HH309 4-channel data logger in New York City. The beds' soil moisture content is being monitored by a Delmhorst KS-D1 Digital Soil Moisture Tester, used with the GB-1 Gypsum Soil Blocks.

RESULTS AND DISCUSSION

At a depth of 8 centimeters, the soil temperature average is between 20-35°C, depending on the weather conditions and the season. Figures 5-7 show the soil temperature from the Hveragerdi experiment.

The Hveragerdi and the New York City heated gardens experienced heating system problems. Both were subject to system interruptions due to steam bore hole temperature inconsistencies; failures in Hveragerdi from earthquake activity, and non-authorized equipment shutdowns and tamperings in New York City. Both also had problematic soil overheating exceeding 45°C at 10 centimeters depth. The Hveragerdi gardens also suffered from wind damage and vermin. The New York City gardens experienced vermin and minor vandalism.

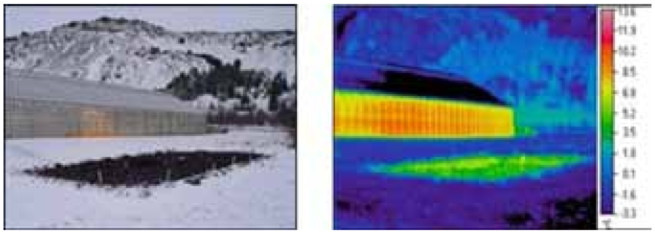

Figure 5: Winter snow cover melted on garden area (left), February infrared image(right)

Despite these limitations, and both location's lack of a sophisticated temperature control and irrigation systems, there were dramatic increases in overall plant growth and yields that mirrored the results of the Harvard Forest soil heating studies (Farnsworth et al., 1992)(Lux et al., 1991).

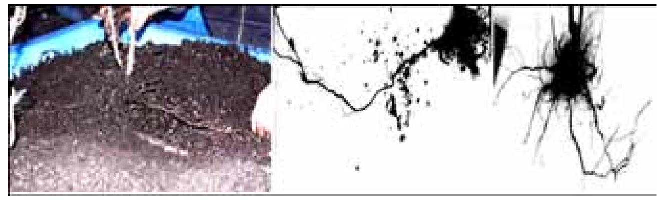

Figure 8: New York City heated garden roots follow pipes; heated bed roots (center); unheated roots (right)

As shown in Figure 8, the tomato plants from the heated beds all had one or two main roots that followed the pipes. The unheated beds produced normal root systems. A United States Department of Agriculture SSL analysis of the New York City 3-year heated garden, when compared to the control garden showed no significant differences (USDA, undated).

In Hveragerdi, as shown in Figure 9, in 2008, the hot water circulated through the heated garden on February 22 had a temperature of 68°C. There was a highly visible strip of green grass directly over the buried hot water pipes. On February 2009 when the water temperature was 48°C, there was no readily noticeable green grass. Both years had similar winter severities.

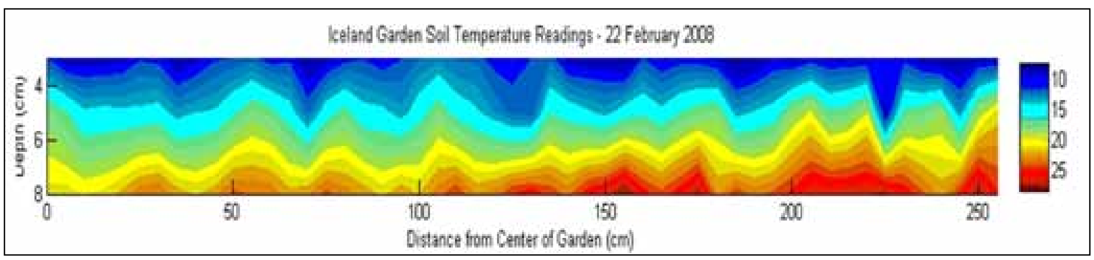

Figure 6: Thermal soil temperature profiles; the temperature peaks are located over the pipes

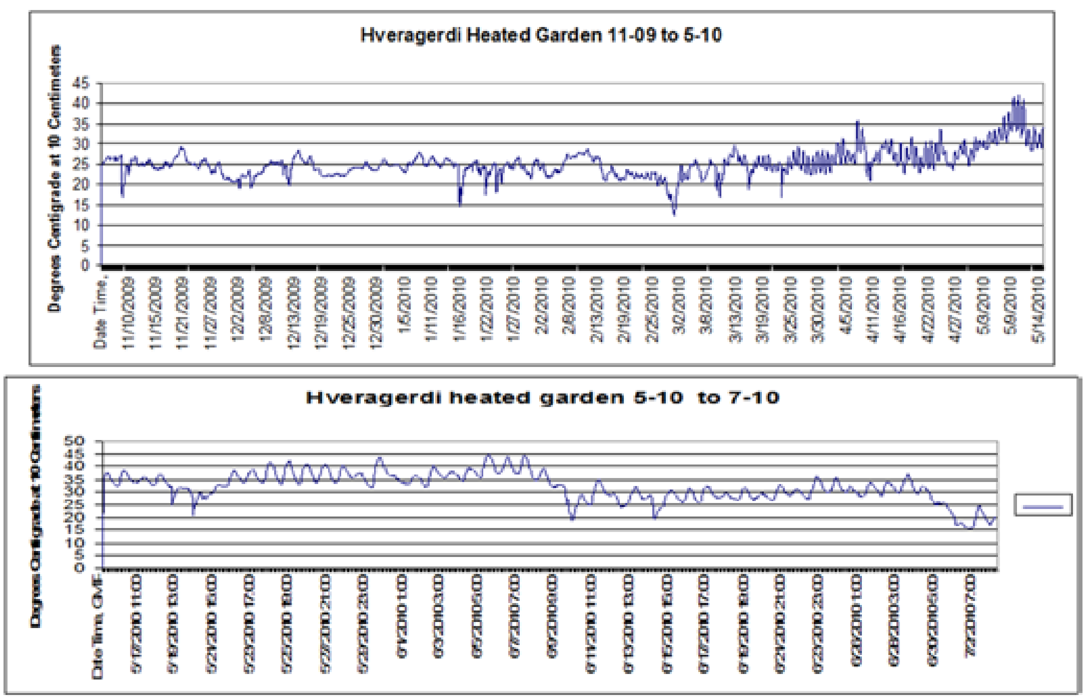

Figure 7: Hobo data logger Hveragerdi soil temperature readings at 10 cm depth from November 10, 2009 through July 2, 2010.

Figure 9: On 02/22/08 temperature reading 68°C, green grass (left two); On 02/22 09 temperature reading 48°C, no green grass (right two).

The heated tomatoes grew by 32% over the duration of the data collection, while the cucumbers grew 7.11% in the same time. The unheated tomatoes had gotten smaller by 13.2% and all the unheated cucumbers had died (Figures 10-21).

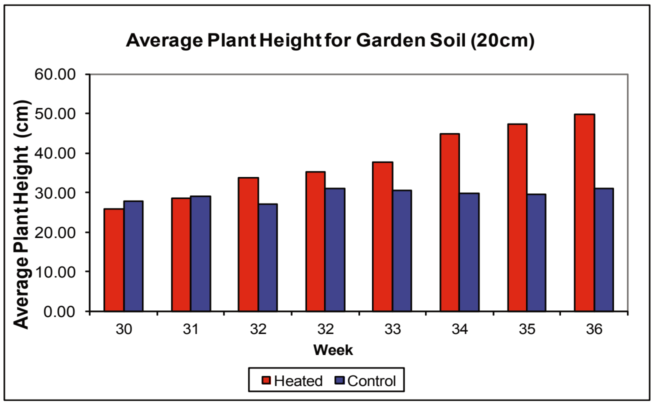

Figure 10: Average plant height for garden soil (20 cm) after 6 weeks (09/06/09).

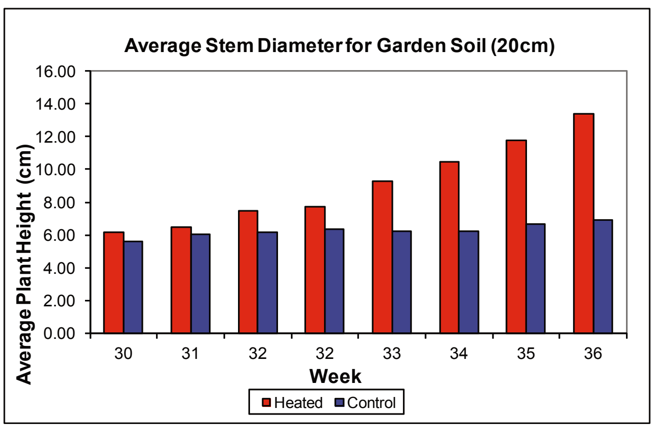

Figure 11. Average stem diameter for garden soil (20 cm) after 6 weeks (09/06/09).

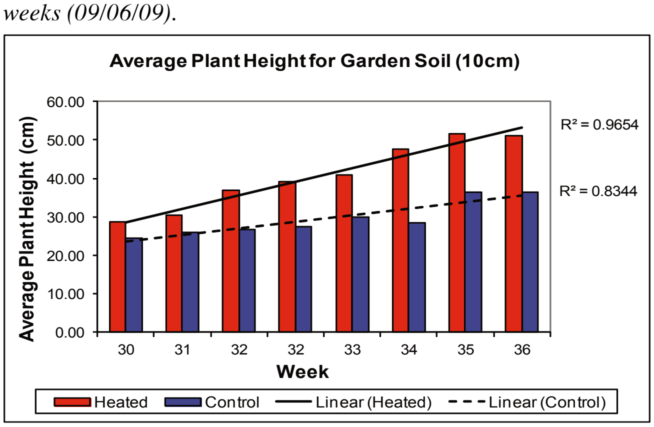

Figure 12: Average plant height for garden soil (10 cm) after 6 weeks (09/06/09).

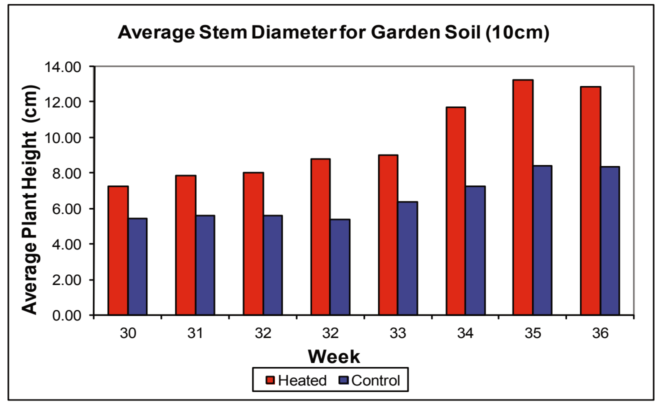

Figure 13. Average stem diameter for garden soil (10 cm) after 6 weeks (09/06/09).

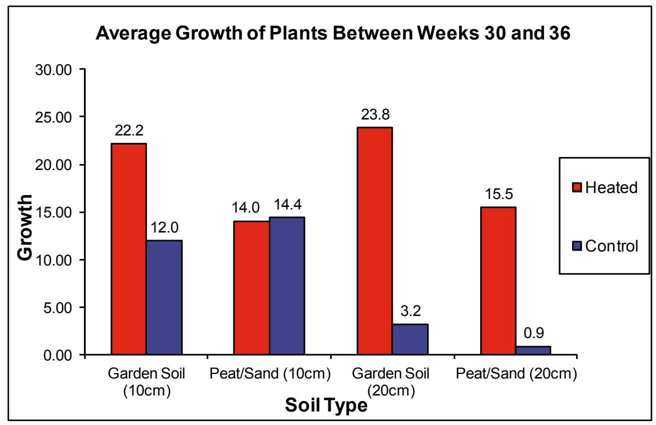

Figure 14: Average tomato plant growth between week 30 and week 36 plant growth.

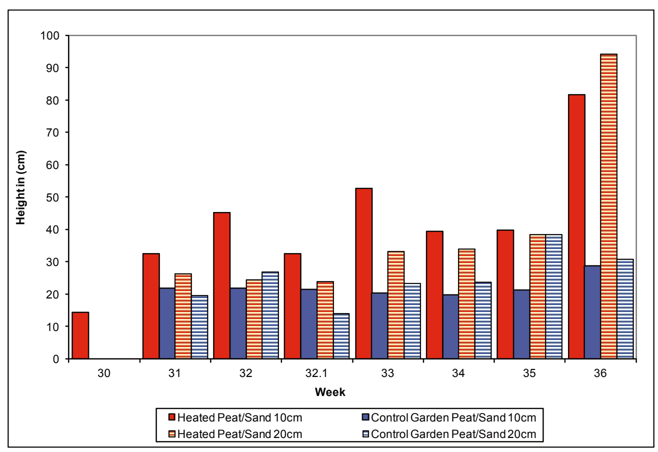

Figure 15: Average plant height for garden Lolium perenne Corvus (grass) between week 30 and week 36.

Figure 16: Iceland garden images. September 20, 2009 after first heavy frost 10 cm heated peat soil tomato and grass (left). September 20, 2009 10 cm control peat soil heated tomato and grass (right).

Figure 17: Iceland tomatoes in 20 cm heated garden soil on September 14, 2009, after 6 weeks in garden, seedling initial height.

The heated tomato plants produced 176% more tomatoes and 63% more fresh weight than the control tomato plants in the 2008 harvest (Figures 18-19).

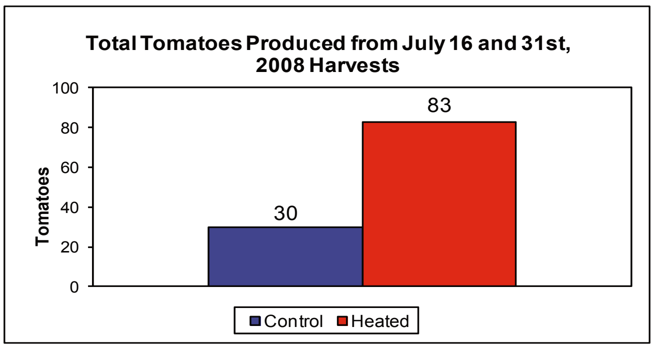

Figure 18: New York City 2008 results for total tomato production from July 16 and 31st.

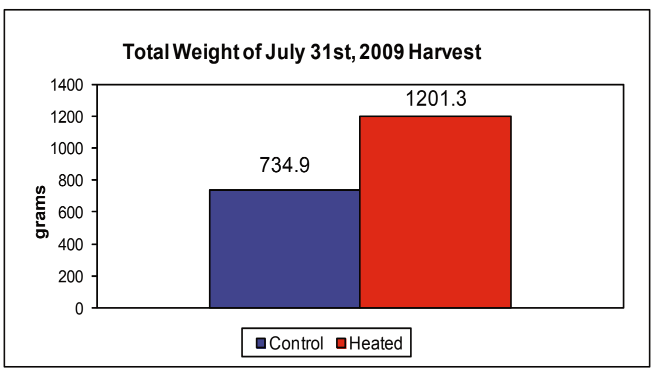

Figure 19: New York City 2008 results for total weight of July 31st harvest.

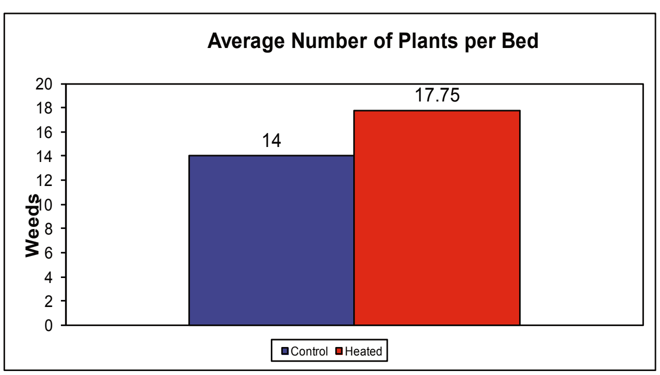

Figure 20: New York City 2008 results for average number of plants per bed.

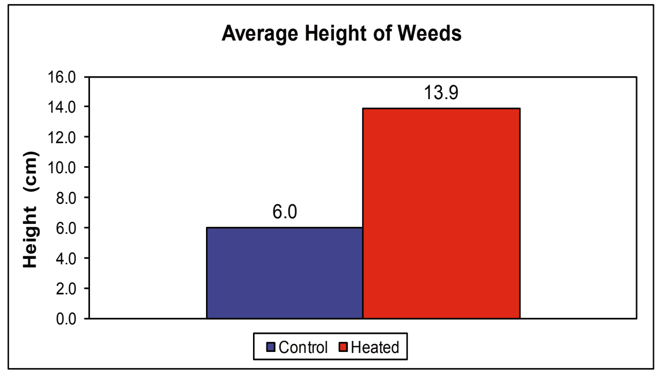

Figure 21: New York City 2008 results for average height of weeds.

Figure 22: New York City garden images. January 20, 2009 Pansies (left). January 20, 2009 control and heated beds (right).

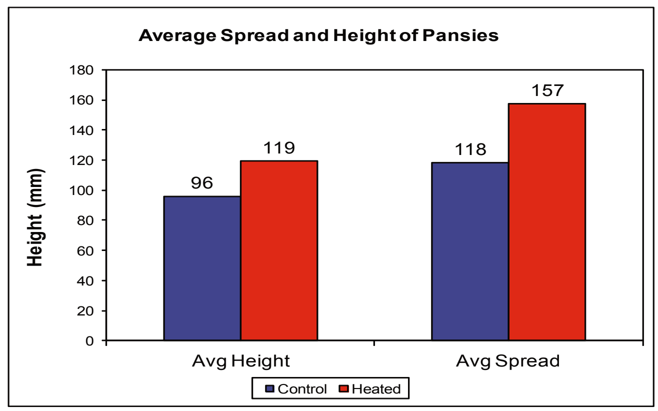

Figure 23: New York City results for Pansy, 4/10/09 average spread and height.

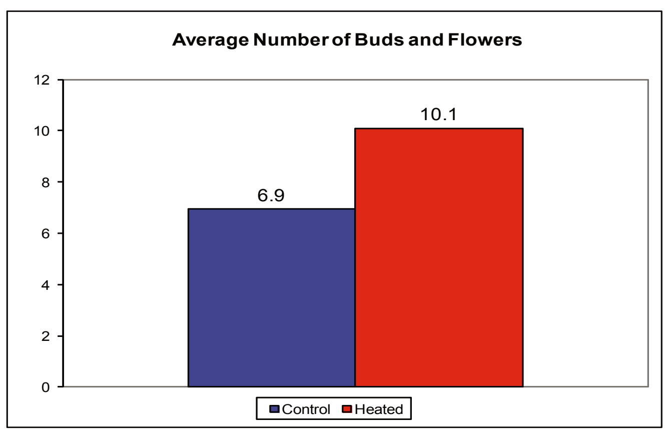

Figure 24: New York City results for Pansy, 4/10/09 buds and flowers surviving over winter.

Pansies are winter hardy in zones 4-8 (Figure 25). They can survive light freezes and short periods of snow cover, in areas with prolonged snow cover they survive best with a covering of dry winter mulch. In warmer climates, zones

9-11, pansies can bloom over the winter, and are often planted in the fall. Their normal blooming season is autumn, early spring and spring.

The New York City pansies in the heated bed were 24% taller, had 33% wider spread, and had 45% more flowers and buds than the pansies in the control bed. They also produced flowers throughout the winter (Figure 23 and 24).

CONCLUSIONS

Tomatoes are only grown in greenhouses in Iceland. The results indicate the outdoor survival of out of region cultivars, such as tomatoes during the growing season in Iceland, (May 15 through September 15), that are normally grown outdoors in warmer climates until the heavy frosts. Average plant growth increases greater than 20% more than the control gardens have been noted. The growing season was increased both in Iceland and New York City by a minimum of four weeks.

The heated garden plants were consistently larger, produced more flowers, and fruit in both Iceland and New York City. The growth and maturation rate of the heated was consistently greater throughout the growing season. The heated tomatoes in New York City had a second flowering cycle, but the cold weather stopped all growth. The grass stayed green throughout the winter in Iceland. The pansies in New York City bloomed in the winter as if they were in Florida.

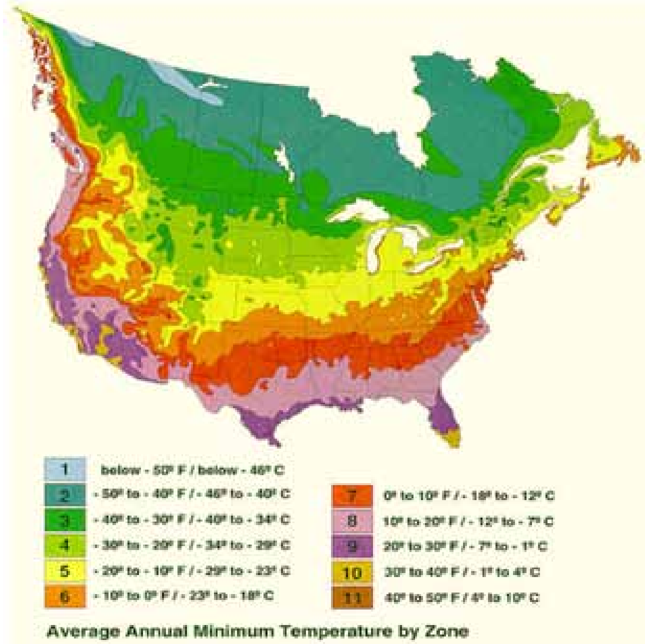

Figure 25: US climate zone map, http://toxipedia.org/download/attachments/15847/zone%20map.jpg

Based up on above results, new heated gardens without heat exchangers are under construction in Iceland at the NLFI Rehabilitation and Health Clinic in Hveragerdi using waste hot water that is currently discharged into the Varma

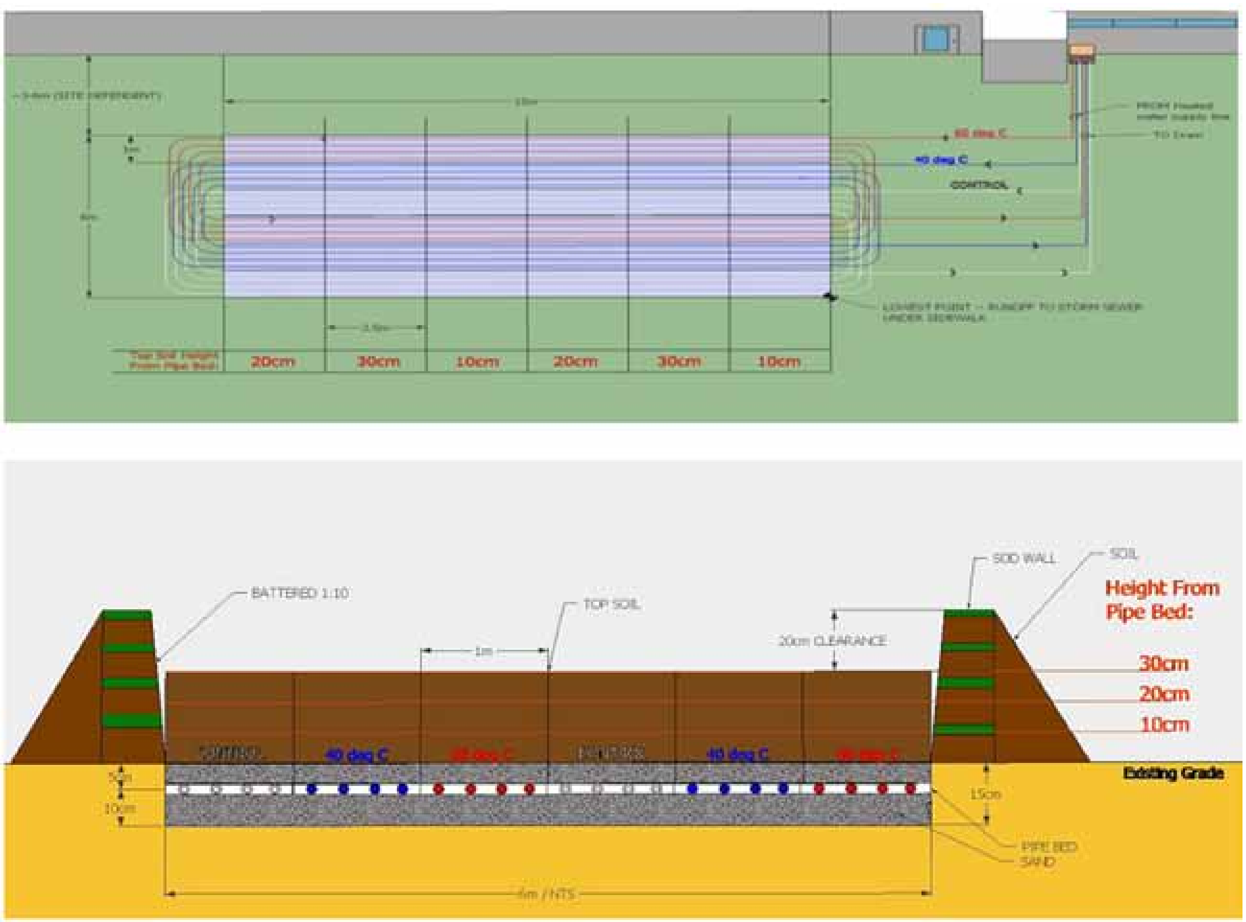

Figure 26: Keilir Institute of Technology Garden Schematics

River. The gardens at the Agricultural University in Hveragerdi will continue with modifications. New gardens at the Cooper Union are under construction. At the Keilir Institute of Technology (KIT) at Asbru in Reykjanesbaer a 16 x 6 square meter garden, as shown in Figure 26, is being constructed to investigate the potential of utilizing the waste geothermal hot water from Icelandic houses to enhance the growth of trees, flowers and vegetables. The garden will have variable water temperature zones from 20-60℃ within individual plots having a soil depth of 10-30 centimeters. Different soil types will be tested. The results will be used for gardens around the buildings in Asbru to increase tree growth.

The increased plant growth, increased bloom and fruit production, coupled with the out of region growth potentials warrants further study on a larger scale.

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http://toxipedia.org/download/attachments/15847/zone%20map.jpg

POWER GENERATION POTENTIAL FROM COPRODUCED FLUIDS IN THE LOS ANGELES BASIN

Kara P. Bennett, Kewen Li, and Roland N. Horne, Dept. of Energy Resource Engineering, Stanford University

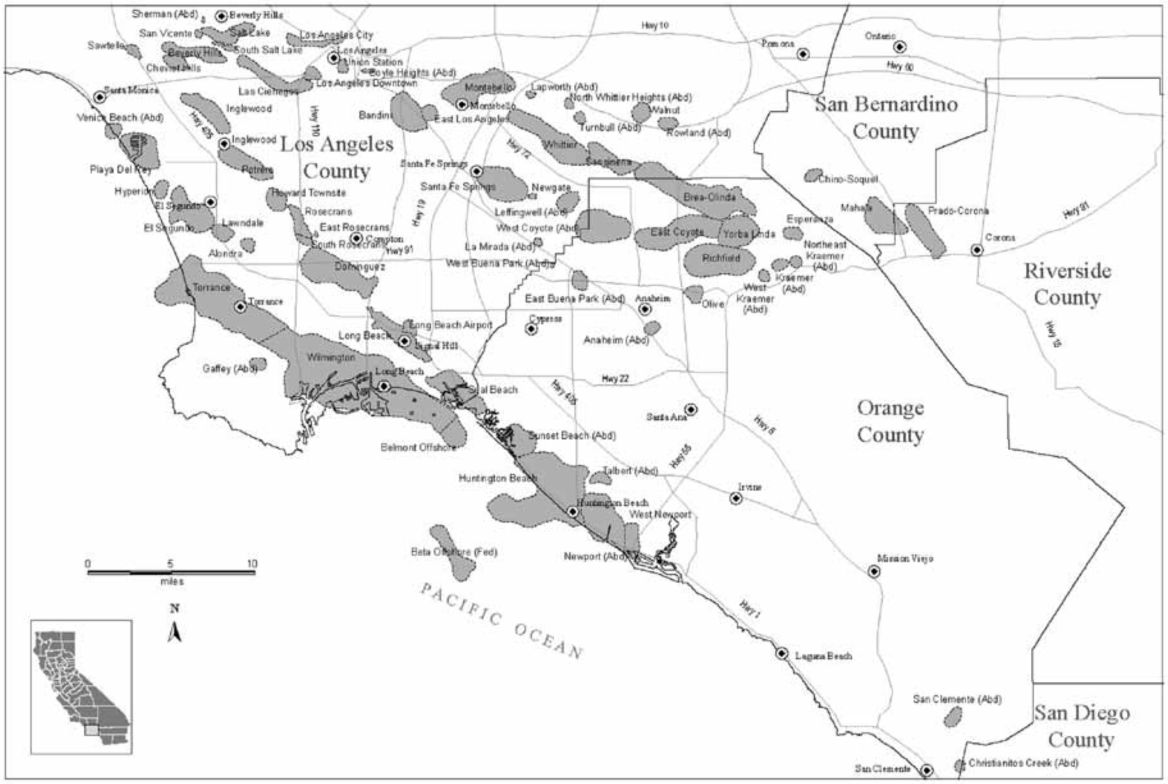

Figure 1. Los Angeles Basin area oil fields (Gamache and Frost, 2003)

EDITOR'S NOTE

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ABSTRACT

There is potential to profitably utilize mature or abandoned oil field infrastructure to produce geothermal electricity, called coproduction. Although many oil reservoirs have only a moderate temperature range, utilizing mature or abandoned oil infrastructure sidesteps the capital intensive initial investment to drill new wells and eliminates the need and associated risk of induced fracturing, a practice currently under much scrutiny in application for EGS. Power generation from coproduced fluids using a binary-cycle power plant is underway at the Rocky Mountain Oilfield Testing Center in Wyoming and being considered in locations in Texas, Louisiana, Florida, and Arkansas. California is another good candidate for coproduction. Although currently there is no electricity generated from coproduced fluids in California, a study by Sanyal et al. 1993, suggested that the oil and gas fields in the Los Angeles basin have a promising geothermal gradient of 2.0°F/100 ft while data collected by the DOGGR for 2009 reveals a 97% water cut for production in Los Angeles County oilfields. This combination of favorable geothermal gradient and large volume of water produced is promising for electricity generation from these coproduced fluids. In this paper, a process for screening potential candidates for coproduction is demonstrated using the Los Angeles basin as a case study. Temperature and production data were incorporated into a simple STARS numerical model to forecast reservoir performance over the course of 30 years and power output from a binary power plant. These results were then used in an economic model to determine the net present value of the project. The most significant parameters to economic viability for a project include reservoir temperature as well as total fluid production rate.

INTRODUCTION

Many mature oilfields produce a large volume of water with the oil as a consequence of water flooding. In some cases the temperature of the produced water falls in the moderate temperature range between 100°C and 180°C. Advances in binary-cycle power technology have opened the door for exploiting these moderate temperature resources. A test facility at the Naval Petroleum Reserve No. 3 in the Teapot Dome Oilfield has demonstrated the viability of power generation from coproduction (Johnson et al. 2010). This Ormat Organic Rankine Cycle power plant was designed to use 40,000 bbl/d of 170°F (77°C) produced water to generate 180kW. The unit was put into operation September 2008 and another unit designed to generate 250kW for three years was planned for delivery in early 2011 (Reinhardt et al. 2011). Another coproducing facility has very recently been installed in Huabei Oil Field near Beijing, China that is producing 300kW (Gong et al. 2011).

Other areas have shown great potential for coproduction application, particularly in the Gulf States (Sanyal and Butler, 2010). Erdalic et al. (2007) reported that Texas alone has thousands of oil and gas wells that are sufficiently deep to reach temperatures exceeding 250°F (121°C). The 2006 MIT report on the future of geothermal energy estimated that between California, Oklahoma, and six other states along the Gulf Coast over 11,000 MW could be generated from coproduced fluids which would double the world's current geothermal capacity. A more conservative estimate predicts at least 2,000 MW from these states.

While Gulf Coast states receive much attention for potential coproduction application California is another promising area for development, particularly in the Los Angeles (LA) basin. The LA basin is home to many giant oilfields and has been under production since the early 1900s. Production in the LA basin in 2010 was 97% water. Also, the LA basin has a promising geothermal gradient of 36°C/km and over 30% of its reservoirs reach to at least 1,800 meters which corresponds to at least 80°C. The LA basin has had a long history of water flooding but also a substantial amount of steam flooding; Wilmington, Huntington, Richfield, Inglewood, and Newport West oilfields have used steam floods, to name a few. After depleting these steam-flooded reservoirs of oil, some of the injected heat can potentially be recovered (Limpasurat et al, 2010). Another factor that makes the LA basin so attractive is the proximity to urban centers. Most of the oilfields in the region are intermingled with the city and thus have immediate access to the electrical grid. Figure 1 shows the oil fields of the Los Angeles Basin.

Wilmington Oilfield is a particularly attractive candidate for utilizing coproduction. Wilmington is the second largest oilfield in the state of California, has been under production since 1932 and has a 97% water cut. The deepest wells in the field reach over 2,500 meters where temperatures exceed 143°C. Operations are primarily conducted from four man-made islands just off the coast of Long Beach where space constraints mandate the use of electric submersible pumps instead of jack-arms for pumping; this represents a huge electricity demand that potentially could be met on site.

A process for screening potential candidates for coproduction is demonstrated here, using the Los Angeles basin as a case study. Temperature and production data were incorporated into a simple STARS numerical model to forecast reservoir performance over the course of 30 years and power output from a binary power plant. These results were then used in an economic model to determine the net present value of the project. The most significant parameters to economic viability for a project include reservoir temperature as well as total fluid production rate.

ANALYSIS

Temperature and Production Data

Temperature and production data from oilfields in the Los Angeles basin were acquired from the State of California, Division of Oil, Gas and Geothermal Resources (DOGGR) databases. Out of the 365 producing reservoirs in the Los Angeles basin, 189 had initial temperature data. Figure 2 shows the temperature versus depth for these reservoirs identifying the oilfields from which the four hottest individual reservoirs are found. A geothermal gradient of approximately 33°C/km is determined which resembles the 2.0°F/100ft (36.5°C/km) geothermal gradient found by Sanyal et al. 1993. The data scatter is in part caused by inaccuracies inherent in the database. One reason for this inaccuracy is that temperatures are usually recorded in wells during logging runs where the temperature may or may not have recovered from the cooling effect of mud circulation, thus temperature records often underestimate the actual reservoir temperature (Sanyal et al. 1993).

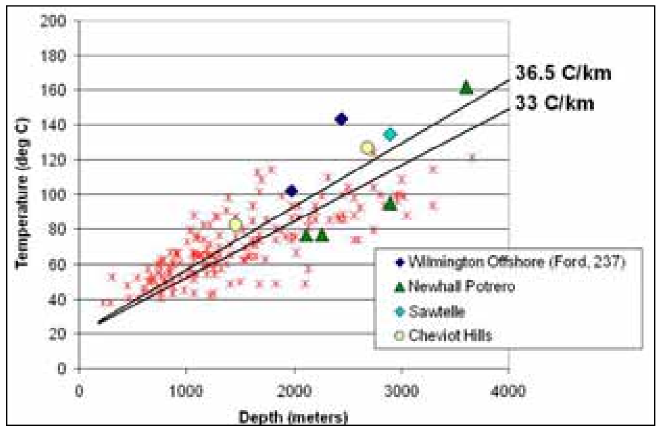

Figure 2. Depth vs reservoir temperature for oil reservoirs in the Los Angeles basin.

Of the 189 reservoirs with initial temperature data, 11% recorded temperatures exceeding 100°C and 32% recorded temperatures above 80°C. Reservoirs with depths exceeding 2,500 meters account for 12% of all the reservoirs which, by following the geothermal gradient, can indicate temperatures exceeding 100°C. Reservoirs with depths exceeding 1,800 meters account for 33% of all reservoirs which, again by following the geothermal gradient, can indicate temperatures exceeding 80°C. Overall, the Los Angeles basin contains a significant number of reservoirs with temperatures within the limits of binary technology to be exploitable through coproduction.

Production and injection rates for March 2011 for each field and reservoir were acquired from the DOGGR databases. Production and temperature data for promising fields are listed in Table 1. Notice that while certain zones of the Wilmington Offshore oilfield show very promising temperatures, the overall average temperature of the whole field is below the limits of being useful for electricity generation. This is because the most prolific zone by far in the Wilmington field, Ranger, happens to be shallower and cooler (61°C). Unfortunately, as geofluids from various zones in the Wilmington field are comingled during production, additional infrastructure may be required to keep the geofluids of different temperatures separate before installing a binary power plant. For this analysis, zones Tar and Ranger in Wilmington field are left out leaving reservoirs Upper Terminal, Lower Terminal, Union Pacific, Ford, and 237.

Table 1. Selected production data for fields of interest

Field	Average Reservoir Temperature (°C)	March 2011 Combined Production (kg/s)	water cut
Beverly Hills	97	49	92%
Long Beach	79	230	97%
Inglewood	68	674	97%
Santa Fe Springs	73	183	98%
Seal Beach	100	43	95%
Wilmington (All)	63	2514	98%
Wilmington (UT, LT, UP, Ford, 237)	77	856	97%

STARS Numerical Model

A numerical model programmed in STARS was used to forecast reservoir performance over the next three decades specifically calculating reservoir temperature decline as a result of mining the heat to produce electricity instead of reinjecting that thermal energy. (Three decades was selected as the typical lifetime of a binary power plant). The model is a basic two well model, simulating a single injector and producer pair in a closed system. The model assumes no aquifer, no heat source or sink, and two fluid phases (water and oil). Reservoir size, temperature, production and injection rates were customized for each simulation while geologic properties including porosity, permeability, viscosity, relative permeability, thermal conductivity, etc. were borrowed from an actual typical sandstone reservoir and used for all simulations. A list of some of the parameters is included in Table 2.

Table 2. Constant parameters for the STARS numerical model

Ambient Temperature	24°C
Injection Temperature	35°C
Power Plant Outlet Temperature	55°C
Porosity	0.30

The STARS model was used to simulate a single injector and producer pair and the results were then properly scaled to represent the entire field. Separation of the oil and water was assumed to occur after running the coproduced fluid through a heat exchanger at the binary power plant. The production rates are significantly lower in these oil wells than what is typically desired for geothermal applications and significant thermal breakthrough within 30 years was not observed for any of the simulations. Later in the economic analysis, it became apparent that sufficient fluid flow is just as or even more important that sufficient thermal energy.

Power Output Analysis

The 2006 MIT report exhibits a correlation for specific power output of a binary power plant considering the inlet (produced) temperature and the outlet (injected) temperature. This correlation is only provided for select inlet and outlet temperatures shown in Figure 3.

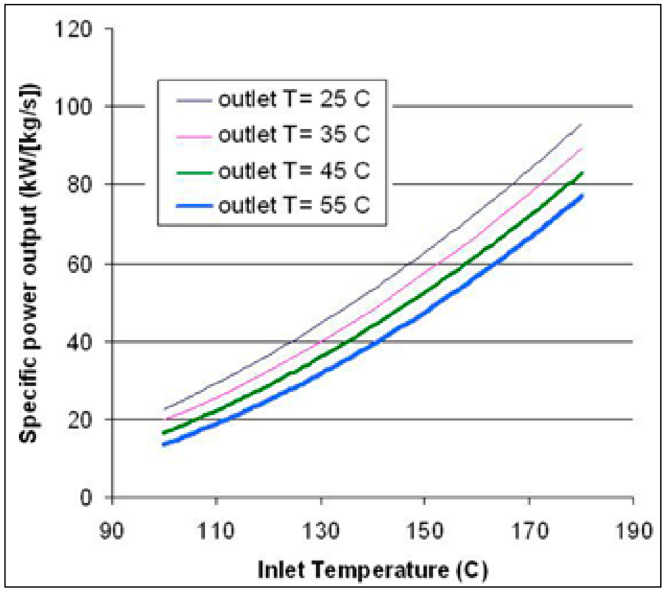

Figure 3. Specific power output in kW/[kg/s] for low to moderate temperature geofluids as a function of inlet temperature (produced temperature) and outlet temperature (injected temperature) from 2006 MIT Report.

A more complete correlation was fit to be able to account for any specified inlet and outlet temperature:

Specific Power =

$$0.0037(T_{inlet} - X)^2 - 0.1217(T_{inlet} - X) - 2.0381$$

Where $X = 0.5638T_{outlet} - 14.507$

Economic Analysis

Basic economic assumptions are listed in Table 3. The electricity generated by coproduction is assumed to be used on site to offset the electricity purchased from the grid at $0.08/kWh instead of being sold to the grid at the lower wholesale price (EIA, 2011). The initial capital cost of the power plant and gathering system includes the cost of the additional pipelines, pumps, on site substation and transmission lines, pollution abatement, legal, regulatory, reporting and documentation, as well as the power plant itself which comes to around $1,900/kW installed capacity (GeothermEx, Inc, 2004). There are no exploration or development costs involved since the oilfield infrastructure is already in place. No tax rebates are included in hopes of viability without tax credit intervention. On a similar note, taxes and specifics of project financing are not addressed in this analysis. Other relevant parameters not explicitly mentioned are also listed in Table 3. A project is considered economic only if it has a net present value (NPV) exceeding $1M at the end of 30 years, a typical lifetime for such a power plant.

Table 3. Basic economic parameters

Electricity Price	$0.08/kWh
Initial Capital Cost	$1,900/kW
Operation and Maintenance	$0.014/kWh
Power Plant Capacity Factor	0.85
Discount Rate	5%

RESULTS AND DISCUSSION

This analysis covers 49 active oil fields in the LA basin incorporating 365 individual reservoirs. All together, these fields have the potential to produce 8.2 MW for 30 years using a power plant outlet temperature of 55°C. (Potentially employing water cooled systems and thus a power plant outlet temperature of 35°C could boost production to 18.7 MW). Figure 4 shows the power potential from each of the 49 fields compared with the economic success criteria labeling only select fields. Only six fields have a sufficient temperature and flow rate in order to be economic independently: Beverly Hills, Long Beach, Santa Fe Springs, Seal Beach, Inglewood, and select reservoirs of Wilmington. Together these six fields total 7 MW. Table 4 shows the power plant size that can be sustained for 30 years by the forecasted production rates and temperatures of the fields as well as the net present value of each of the projects.

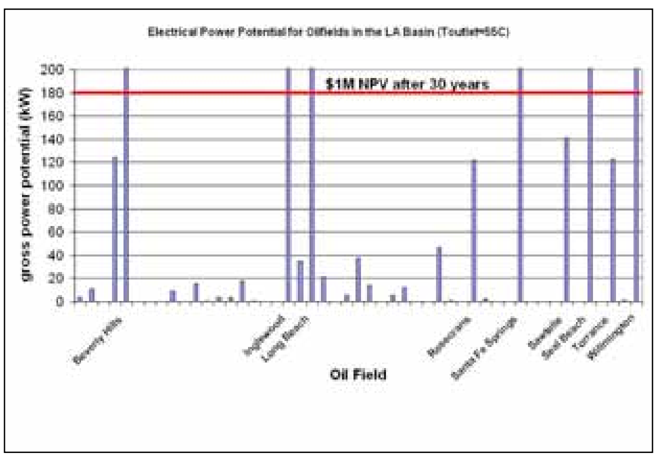

Figure 4. Gross power potential from each of the 49 active oilfield in the Los Angeles Basin with the economic success criterion of $1M NPV after the 30 year life of the power plant. The gross power potential scale is terminated at 200 kW to detail the smaller fields.

The six fields that are economical end up being those with only moderate temperatures but prolific flow rates demonstrating that sufficient flow is just as, or even more, important than reservoir temperature. To demonstrate this consider Newhall Potrero oilfield which has the highest recorded temperature in the LA basin: 162°C in zone 7. Development of this zone alone results in a 9 kW power plant sustained for 30 years but uneconomic. Although the temperature of the reservoir is sufficiently high, production rates are not, which seriously limits the potential power generation. Considering all zones in the Newhall Potrero field results in a 14 kW power plant sustained for 30 years which is still uneconomic. It is observed that even lower producing temperatures can be compensated for by higher production rates which explains why the largest fields, and not necessarily the hottest, are the most economic for coproduction.

Table 4. Power plant size that can be sustained for 30 years and the net present value.

Field	Power Output (kW)	NPV
Beverly Hills	1,080	$3,283,431
Long Beach	530	$5,995,589
Inglewood	580	$6,095,423
Santa Fe Springs	1,100	$2,945,104
Seal Beach	590	$3,205,782
Wilmington (UT, LT, UP, Ford, 237)	3,550	$19,650,668

The Wilmington Offshore oilfield represents a lower limit to this trend of trading extremely high temperatures for higher flow rates. Excluding the two shallowest and coolest zones, Ranger and Tar, the Wilmington oilfield can sustain a 3.55 MW power plant for 30 years which results in NPV of over $19.6 million. In this case, the development scenario cannot be improved by incorporating more lower temperature zones to boost production. The most prolific zone in the Wilmington Offshore field, Ranger, accounts for 84% of the entire production and unfortunately has a reservoir temperature of only 61°C. The temperature of the produced fluid after comingling is only 63°C. Unfortunately this happens to be the case for production in Wilmington offshore at present – geofluids from multiple zones are comingled in the production process. New infrastructure might be necessary before utilizing Wilmington offshore for coproduction.

CONCLUSION

This paper presents a process for analyzing potential reservoirs for coproduction using oilfields in the Los Angeles basin as a case study. Potential developments are ranked according to the size of power plant it can sustain for a typical power plant life time of 30 years as well as the net present value of the project. Six fields are shown to have sufficient flow and reservoir temperature to be economic independently: Beverly Hills, Long Beach, Inglewood, Santa Fe Springs, Seal Beach, and select zones of Wilmington. Taking a closer look at the single hottest reservoir in the LA Basin, Newhall

Potrero's zone 7, demonstrates that sufficient production rate is as important to development as reservoir temperature.

This analysis is executed on a by field basis but perhaps a second analysis by operator is warranted since multiple operators developing from the same field would most likely be unwilling to comingle production for a binary power plant.

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"GOT DATA?"
FOUR-HOUSE COMPARISON OF HVAC OPERATING COSTS

John D. Geyer, C.G.D., John Geyer & Associates, Inc., Vancouver, Washington

Figure 1. Four Home Cluster in Stevenson, WA.

Scarcely a month passes without at least one caller to John Geyer & Associates, Inc. seeking "real-world" operating cost data for geothermal heating systems. Cost and complexity of utility-grade monitoring and verification ("M&V") protocols makes such data uncommon and selective. Nobody wants to spend money to document results after installation. As a result, unfounded perceptions, as held by Bonneville Power Administration and West Coast investor-owned utilities are that "Geothermal heating and cooling is not cost effective here", regardless of where "here" may be. This view persists despite 15,000 to 20,000 operating geothermal systems in Northwest service areas and perhaps half as many more in California.

Need to respond to entrenched prejudice prompts geothermal consultant and Certified Geothermal Designer John Geyer of Vancouver, Washington to track actual operating costs for geothermal systems that he designs and installs. A neighborhood in Stevenson, Washington, 30 miles east of Portland in the Columbia River Gorge, provides uncommon opportunity for head-to-head comparison with traditional technologies. With cooperation from customers and neighbors, multi-year operating cost data were compiled for two geothermal, one propane and one air-source heat pump homes on the same street. All residences were reasonably similar in terms of similar age, size, construction quality and occupancy.

The key to cost-effective, practical analysis of geothermal heating and cooling costs is dissection of gross utility bills to isolate HVAC energy costs. Utility payment histories were reviewed for each home. This spanned four and seven years for geothermal homes, five years for the propane home with electric air conditioning, and six years for the air-source heat pump home. Annual HVAC cost for each home is expressed as the average of all years.

Both of the geothermal heat pumps studied provide space heating and cooling and domestic water heating without auxiliary back-up. The propane home uses propane for space and water heating and electricity for air conditioning. The air-source heat pump heats and cools while domestic water is warmed by an electric water heater. Both propane and electric costs were evaluated in the propane home.

To isolate HVAC costs from other electric usage, the two lowest energy payments in each year were identified and averaged. These periods were commonly May-June and mid-September to late-October when ambient temperatures are close to desired indoor conditions; thus, little or no heating or cooling is required. These two minimum payments are averaged and accepted as the structure's "non-HVAC energy use". This dollar amount is subtracted from each bi-monthly utility payment to approximate that billing period's heating and cooling expense.

Geothermal systems heat domestic water but service for occupancy by one or two people was deemed minor compared to energy used for space conditioning. As such, water heating expense was not isolated or excluded during heating cost analysis. It is estimated that subtracting water heating values would reduce geothermal's electric energy use by 10 percent, more or less, but this proxy method of data collection does not lend itself to such precision. A trade-off of classic M&V accuracy for insight to relative HVAC values was deemed acceptable in the absence of answers sought by so many. Magnitude of cost variances in study findings affirms this practice.

Occupancy history of the 2,950 square foot propane home enhanced data analysis and further encouraged combination of space and water heating costs. During two of five years' data, the house was vacant in all months except July as owners worked and lived out-of-country for the balance of year. During vacant periods, no propane was used for water heating and minimal electricity was required. By the same HVAC cost analysis as used in occupied homes, resulting HVAC-only costs during two years of vacancy were ~25% lower than HVAC during occupancy. One-third of the occupancy-related increase (~8%) was assigned to gas-fired water heating and found comparable to water heating's energy allowance in geothermal homes.

Figure 2 . Propane Home

Both geothermal homes were new construction intended for retirement. The first builder drilled a dry water well to 350 feet and asked: "I'm $30,000 into this hole; what can we do with it?" Geyer proposed installing a single 1.25" High Density Polyethylene loop, 710 feet in length, into the cased well bore to support a four-ton Command Air heat pump with de-superheater for domestic water heating. Building size was 3,340 square feet with a daylight basement.

Figure 3 . First Geothermal Home.

The second home had 5,100 under roof with 3,586 square feet of conditioned space. A two-car garage and carpentry shop were not heated. First floor walls were of Insulating Concrete Form blocks and construction quality was "superior". 5,800 feet of 0.75" HDPE piping formed a "slinky 'mat' loop" for a 6-ton Hydron Module heat pump and de-superheater. This loop has two layers of "Slinky-style" pipe coils at -5 feet and -9 feet below grade in a 30 X 70 foot pit. Uncertainty regarding late-summer soil moisture content was offset by over-sizing the ground heat exchanger 20% relative to the heat pump.

Figure 4. Second Geothermal Home.

Figure 5. ASHP home.

Table 1. Average Annual HVAC and Hot Water Expenses for the four homes

	Heating System	Size of Home (sq. ft.)	History	Type of Heating	Cost for Heating	Propane + Electric A/C
Home 1	Propane	2,950	2007-2009 (occupied)	HVAC + DHW	$3,316	$3,933
			2010-2011 (vacant)	HVAC + DHW	$2,449	
Home 2	Air Source HP	2,200	2006-2011	HVAC + DHW	$1,126	
	Adjusted Size	3,000	2006-2011	HVAC + DHW	$1,535	
Home 3	Geothermal #1	3,340	2005-2011	HVAC + DHW	$426	
Home 4	Geothermal #2	3,586	2008-2011	HVAC + DHW	$463	

Shaded boxes are best estimates of "like" comparisons.

Due to panoramic views overlooking the forebay of Bonneville Dam, each home has expansive glazing on the south side. Ventilation features of each include range hoods, indoor spa tubs, fireplace flues, vaulted ceilings, whole house fans and vacuum systems. Of all installed HVAC equipment, only the high-heat burner capacity of the propane house was oversized (+~40%).

Local climate conditions create 5,400 heating degree days with only modest cooling during summer afternoons. Relative humidity is not an issue so all four residential HVAC systems are sized for heating needs. The Columbia River Gorge is a mile-wide, 4,000 deep, water-grade passage through the Cascade Mountain Range known for windy summers and bitterly cold winter storms. Gorge winds routinely seek to equalize pressure and temperatures between dry, continental air east of the mountains and wet, marine conditions on the West Side. Hot and dry or freezing Gorge winds cause seasonal weather extremes in the Portland, Oregon area.

While each home owner provided full or nearly complete records of utility payments, data gaps were filled by payment histories from Skamania Public Utility District No. 1 in Carson, WA. This utility's energy rate is $0.062 per kWh and the bi-monthly service charge is $16.90 with no significant surcharges. Average propane cost over five years (2007-2011) was $2.67 per gallon.

Kilowatt and cost data were complete for each of the four homes studied, with exception of three missing entries that were filled with averages of same-month payments in other years. The review used first-order knowledge of geothermal design and construction and full payment records from original owners/occupants of all homes. While actual costs were computed for the smaller air-source heat pump home, costs were inflated to represent a 3,000 square foot structure for comparative purposes.

These results correlate well with estimates of energy yield and costs for various fuels as prepared by national and regional HVAC authorities and electric utilities. Calculated HVAC percentage of total load in each home is just above 40%.

Previous geothermal installations in the central Columbia River Gorge include the North Bonneville City Library (1997), North Bonneville Hot Springs resort (2000), and 30 to 50 private homes. Continuing research will document costs as they become available but this study confirms that geothermal is, in fact, extremely cost competitive in this long-term, same-street comparison. Monthly heating, cooling and hot water costs below $40 per month for homes greater than 3,000 square feet are "cost effective" in any setting. Anecdotal accounts from Northwest residences on both sides of the Cascade Range are commonly $350 to $450 a year for 2 to 4 bedroom homes of standard construction and 2,000 square feet.

PAISLEY OREGON GEOTHERMAL PROJECT

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EDITOR'S NOTE

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PROJECT

Surprise Valley Electrification Corporation (SVEC) Geothermal Project at Paisley, Oregon is a unique project where a rural electric utility and nearby ranchers are working in cooperation to produce renewable power. Rural electric cooperatives have played a major role in bringing electrical power to rural America and they are now poised to play a major role in developing small geothermal resources scattered throughout their service territories. Rural electric cooperatives were formed in the early 1900s providing a critical mechanism to build and maintain power systems throughout the nation and especially in rural areas, including the western U.S.

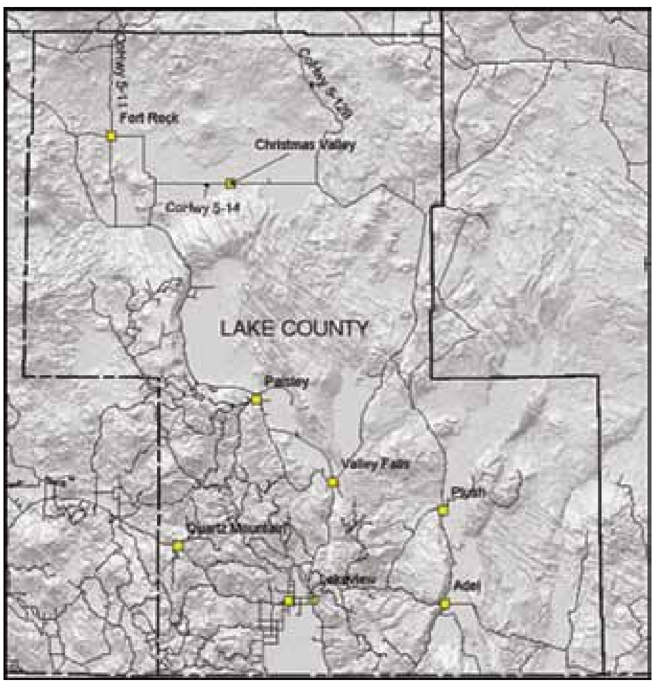

Figure 1. Location of Paisley, Oregon, (Clark Niewendorp, June 2005).

The distribution systems operated by the rural electric cooperatives in the western U.S. serve many small communities and reach rural areas where substantial geothermal resources exist. In fact, many ranchers throughout the West have inadvertently tapped into hot water during development of ground water for irrigation purposes. The combination of the local rural electric cooperative and ranches with hot wells make a good team to develop geothermal resources within their service territory.

The development of small modular low temperature geothermal power systems within the last few years has opened a large potential market. Not too many years ago geothermal power development was only viable for geothermal resources with temperatures of 300°F or above. Newer binary systems are now allowing development of geothermal resources between 200 and 300°F. Chena Hot Springs Resort near Fairbanks, Alaska is producing electrical energy at temperatures of 165°F. Other systems, such as one in Klamath Falls, Oregon at the Oregon Institute of Technology, are also producing power at temperatures below 250°F. The system at the Oregon Institute of Technology is productive at 195°F.

Figure 2. Northwest Rural Electric Cooperatives (Northwest Requirements Utilities)

Rural electric cooperatives have recently become very interested in this low temperature binary power production for several reasons. First, it is a base-load renewable energy with a very high availability, above 90 percent; without intermittent and unpredictable power issues such as wind and solar, and without the price volatility of fossil fuel based power. Second, the generation technology is in modular form making it easy to install and it can be tied into the rural electric grid without major transmission upgrades. The modules range in size from 250 kW to 5 MW and are often at remote locations at the end of the rural electric cooperatives' lines. By having base load power in these locations, it serves the cooperatives' grid well; reducing the potential power outages at remote locations on their service system and converting their investment in transmission into a two way system where excess power can be sold at market prices. Modern modular power systems are also easier to operate and maintain as a result of technology built into their systems allowing the rural electric cooperative to operate and maintain the systems with local experienced staff. Finally the rural electric cooperatives are organizations of, by, and for their communities, and they have a vested interest in developing sustainable economic activity in their service territories. Whereas the typical geothermal development company has a high overhead, a high level of debt, and a requirement to make a substantial return on investment, rural electric cooperatives have small overheads, small debt and no profit requirement. They are literally entities of the rural areas they serve. On a financial basis this makes a significant difference. One of the ways this is most obvious is the level of cooperation between the ranchers and the utility. They have been business partners for years and this is a logical extension of that business relationship.

The rural electric cooperatives, being owned and financed at the local level, have established mechanisms to work with local ranches, farms, and rural communities to develop the geothermal resources in their area. They supply power to the same ranches which have hot wells and/or geothermal potential beneath their lands and therefore are often looked at by the owners of the resource as the logical group to develop the resource for local use. The project at Paisley, Oregon is a good example of a rural power development project which has involved the local rural electric cooperative teaming together with local ranchers to develop geothermal energy. The project in Paisley did not start with the electric cooperative. The issue with any project, no matter how large or small, is who puts up the initial risk capital. The project in Paisley was first initiated through a feasibility study partially funded by USDA (75%) and matched by a 25% contribution from others.

Interestingly Chevron Energy Solutions (a business unit of Chevron) was the matching entity identified in the USDA grant application. However, between the time the study was submitted and funded (about 6 months), the account executive with Chevron involved in the project, took a new position with the start up geothermal company Altarock Energy. To its credit Chevron simply allowed the project to follow the account executive and Altarock agreed to supply the match. After about a year, Altarock Energy, with a completed feasibility study, decided it did not want the project because the project was not an Enhanced Geothermal System (EGS) candidate. The project however had gained momentum since the feasibility had identified a resource that could produce economical base-load power.

Dennis Trexler and Dan Hand were the authors of the USDA Feasibility Report, which recommended further development. There was little question about the resource and the need for base-load sustainable power was great. Surprise Valley Electric Corporation (SVEC), the local electric cooperative, became interested in the development of the resource. SVEC had known about this resource since the early 1980s, when the rancher discovered the 235°F water while drilling for irrigation water. In fact the rancher has used this water for irrigation since 1981 to grow high quality alfalfa hay. While the water from this resource has been used, the thermal energy has been wasted. The rancher, who drilled the well for irrigation water for his ranch, built a 2 acre cooling pond to cool the water before applying to his crops. This has been a common practice with many irrigation wells in Oregon, Idaho, Nevada and Utah which have temperatures too high for application on crops.

Although the feasibility study recommended development, without a development partner, this project was going nowhere. The rancher was unwilling to put his ranch at risk to acquire risk capital and the traditional geothermal development companies were just not interested in a small project. That is when SVEC stepped in and became the developing partner. SVEC understood the power application could be integrated into the ranch in a supportive way. The cooler water from the discharge of the power plant actually improves the irrigation quality of the water and the thermal energy provides another source of income for the ranch and helps keep rural electric rates inexpensive. So, with a solid partner behind the project, things began to happen. First SVEC funded an extended flow test which validated a minimum resource flow rate and temperature using the existing irrigation well and pump. The rancher also contributed to the flow test with on-site support (dozer, backhoe, welding, and food service) and the rancher agreed to pay the cost for replacing the 10 inch threaded pipe in the well. SVEC was particularly pleased with the flow test, not in the least because the ultrasonic flow meter they used for testing irrigation wells validated the flow results produced by the consultants. With a solid flow test, SVEC hired two consultants, Dr. Roy Mink of Mink GeoHydro and Dan Hand of Sustainable Engineering, to guide the project along. With SVEC funding the consultants have secured support funding from the following programs:

1. The US DOE Geothermal Technologies Program. A 2 million dollar grant that is currently helping to fund exploration work and will later contribute to the purchase of the power plant equipment.
2. A preliminary guarantee from the State of Oregon for a Business Energy Tax Credit worth up to 35% of the project. This program contributes to the project only after it is on line and producing green power.
3. An allocation of Clean Renewable Energy Bonds which will provide project financing at rates well below commercial lending rates.
4. Production well drilling is being under taken by Surprise Valley Electrification Cooperative.

As a result of the funding grant from the DOE Geothermal Technologies Program, SVEC has funded a 2 meter probe survey, a gravity survey, and geological studies to keep the project moving forward. Although the original plan was to use the existing well, SVEC has decided to drill a new well because of the risks involved with upgrading the existing well to geothermal requirements. SVEC has selected a driller and is expected to complete the drilling work in the summer of 2011. Since modular equipment is available from several manufacturers SVEC is also in the process of selecting the equipment manufacturer. Rural electric cooperatives have several key advantages over traditional geothermal development entities that make them an ideal developer of small geothermal resources.

1. Rural Electric Cooperatives know the community and have existing business relationships with large property owners.
2. Rural Electric Cooperatives have access to low interest loans and are not leveraged with significant debt.
3. Rural Electric Cooperatives own the power lines in rural areas, often right at the resource and typically can take up to 10 MWs of power without significant transmission work.
4. Often the small resources that are not of interest to traditional development companies are well known and the amount of risk is suitable for the rural electric cooperative.

Plant construction for the Paisley Project is expected to be occurring by fall of 2011 with power on line scheduled for 2012. The project has moved very smoothly with resource work conducted by a retired professor from the University of Oregon, Dr. Silvio Pezzopane and a graduate student from Boise State University, Kyle Makovsky, with assistance from Dr. Roy Mink and Lynn Culp. Lynn is the Member Service Manager from SVEC and he has directed the local manufacturing of several useful geothermal assessment tools, including a well logging wireline, a weir, flow test equipment and a complete 2 meter probe set of equipment. Engineering and project direction was done by Dan Hand of Sustainable Engineering. Dan Silveria, Surprise Valley Electrification Corporation General Manager, is the over-all project manager. Considerable field and logistical support was supplied by the Colahan Ranch.

Figure 3. Paisley Drilling, May 2011.

By way of extension SVEC is looking into the development of other geothermal resources within its service territory and the local region. Another local entity, Klamath Water and Power Agency (a group of Oregon ranchers) is looking into the resources in its service area. This development model is one that finally harnesses the well known resources the geothermal community has been aware of for years; and it does it from within the community. It is also of note that SVEC's interest has gained notice from traditional developers and supports a healthy development market. This is good for resource owners and equipment manufacturers; and encourages other rural electric cooperatives to get into the market.

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