Geothermal Energy in Oregon 2014

Alex Sifford
Sifford Energy Services, Neskowin OR, USA
alexs@oregoncoast.com

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ABSTRACT

Thirty two years ago a geothermal power plant commenced operations near Lakeview Oregon. While it operated for only 12 months, it represented a milestone that was only exceeded in 2010. This paper touches on direct use but focuses on geothermal power exploration and development efforts in Oregon.

Today, in 2014, power plants using geothermal fluids operate in three Oregon counties: Klamath (OIT), Lake (Paisley) and Malheur (Neal Hot Springs). Geothermal explorationists are actively working at six prospects around the state. They are located at Newberry volcano, Crump Geyser, Klamath Falls, Vale and Glass Buttes. These sites may have as much potential as 150 MW.

Location

Oregon is located along the Pacific Ocean north of California where tectonic plates collide. Abundant centers of young volcanism form the backbone of the region (fig. 1). Eruptions in the Cascade Range have been occurring for over 500,000 years. During the past 4,000 years eruptions have occurred at an average rate of about 2 per century (USGS, 2009). The dramatic 1980 eruption of Mt. St. Helens in Washington was the most recent magmatic eruption in the Cascades Range. Heat-flow coming from magma at depth (>10km / 6 mi.) is concentrated along the Cascade Range (Blackwell, et al. 1990.) Few deep wells have been drilled to confirm the elevated heat and potential geothermal resources. However, wells drilled at Newberry Volcano in Oregon and in the Cascades of British Columbia have found temperatures in excess of 200°C (500°F).

Oregon contains nine physiographic provinces as shown in fig. 2 (Orr and Orr, 1999). Fault-related hydrothermal systems occur in the older ancestral Western Cascades, and igneous-hosted hydrothermal systems occur in the recent volcanic of the High Cascades. Numerous low to moderate temperature hydrothermal systems occur in the faulting of the High Lava Plains and Basin and Range Provinces of Oregon. Newberry Volcano in central Oregon, is located in a transitional zone between the High Cascades and the Basin and Range Faulting. It’s positioning is similar to that of Medicine Lake Highlands, California and Mount Adams, Washington. Newberry last erupted about 1,350 years ago.

Population centers and geothermal resources are shown in figure 3. Energy is primarily consumed in the northwest corner of Oregon while the eastern two thirds of the state contain some level of geothermal energy resources.

In Oregon today the Geo-Heat Center at Oregon Institute of Technology identifies 2195 individual resources shown in Figure 4 (GHC, 2007 modified by ODOGAMI, 2014).

Figure 1. US Pacific Northwest Cascade Range Volcanos.
Native Americans used hot springs in numerous Oregon locations. OIT estimates there are 630 applications in Oregon that provide 626,703 gigajoules (594 x 10^9 Btu) of energy per year for space heating, greenhouses, aquaculture, pools and resorts uses. Many cities and towns in the eastern two thirds of the state use geothermal energy.

Klamath Falls boasts that a person can go from birth through death, all in geothermally heated facilities. These buildings include the local hospital, elementary schools through college, brewpub, homes, businesses, municipal buildings, assisted living facilities and a funeral parlor.

The Oregon Institute of Technology campus in Klamath Falls uses 89°C (192°F) geothermal water to heat its campus. It has done so since 1962 when the school location was deliberately chosen for the underlying geothermal resources. The OIT campus is home to the respected Geo-Heat Center.

The City of Klamath Falls Geothermal Utility provides cost-effective heating services using renewable, non-polluting hot water. Klamath Falls is located in a US Geological Survey designated Known Geothermal Resource Area (KGRA). Utilizing geothermal water supplied from wells producing 94-105°C (200-220°F) water, the City operates a geothermal utility system which provides heating services to commercial and government buildings throughout the downtown core area as well as geothermal sidewalk and bridge snow melt systems (fig. 5). The sidewalk and bridge snow melt systems provide safety and convenience throughout the winter months that would not be obtainable without low cost geothermal energy.

The benefit of geothermal heating is lower energy costs and better air quality compared to other sources. As oil, natural gas and electricity costs continue to increase, the cost of providing geothermal heat remains low along with providing a much higher heating efficiency than other heat sources.

Lakeview, Oregon has long experience using local geothermal resources. The Town of Lakeview has wells and a system designed for increased commercial users. Geothermal wells in the area have temperatures up to 96°C (205°F). The range of geothermal applications includes a commercial greenhouse op-
eration, space heating of individual homes, a hotel, four schools, hospital and a state corrections facility. The Town of Lakeview recently completed a $3.6 million system connecting the schools and hospital with the option for additional district heating.

Vale hot springs, near the Idaho border, was a stop for early settlers on the Oregon Trail. A mushroom plant used those same 97°C (207°F) waters in its operation until closing in 2007. Seasonal agricultural processing and modest space heating applications exist there. And in early 2014, US Geothermal began assessing public and private property near Vale for high temperature resources.

La Grande has warm water within City limits. Hot Lakes Resort, just south of La Grande, was renovated beginning in 2005 with the Hot Lake Springs Gallery and Foundry. In 2010 overnight guests were once again welcomed (Hot Lake Springs, 2014). Burns and other areas have useful geothermal resources for space heating, greenhouses and pools.

Isolated hot springs and resorts are found in the Blue Mountains, Columbia Plateau and along the western Cascades. Some are undeveloped pools and others like Belknap Hot Springs near Eugene are large resorts. Austin Hot Springs is a 151± acre rare private in-holding within the Mt. Hood National Forest southeast of Portland. It is for sale by Realty Marketing/Northwest. The rest of Oregon is suitable for ground source heat pump use. In sum, Oregon has a long tradition of direct use geothermal energy.

Power Development

Past Activities

Wildcat exploration for high-temperature resources occurred first in 1959 with the arrival of Magma Power. Magma affiliate Nevada Thermal drilled a 513 m (1684 ft) well in the Warner Valley east of Lakeview. The well reportedly flowed 121°C (250°F) water. The well began geysering and has since been known as Crump Geyser (Figure 6). Reportedly, vandals from Lakeview put rocks down the well and made it quit geysering. In 1960 Magma drilled a 155m (510 ft) well just north of Lakeview that flowed 103°C (217°F). That well was subsequently put to use heating a greenhouse. (Brown, et al, 1983).

Wildcat power generation occurred in March 1982 when a 40kW Solar Power Systems binary plant operated briefly at the Rockford Ranch south of Lakeview Oregon. Pacific Power & Light (PP&L) contracted in May of that year to buy the output for six months to demonstrate plant technical feasibility using 80°C (176°F) water. Results were largely negative. Later in 1982 three 400 kW Solar Power System binary generators were installed in the Hammersly Canyon area north of Lakeview. The operation used 100°C (212°F) water. In April 1983 three 300 kW Ormat binary generators were added. In March 1984, PP&L again contracted for one year to purchase the plant output of the now 2.1 MW project. Utility research goals were similar to the prior demonstration. No significant operation at the larger plant ever took place. It produced power for one year after which difficulties caused the operation to cease. These included landing a long term power sales agreement, cooling operation, and interference with nearby wells (Sifford, 1990).

Developments described above occurred on private land. Firms looking at larger prospects on federal lands followed leasing guidelines created by the passage of the Geothermal Steam Act of 1970. Federal lands – USDI Bureau of Land Management (BLM) and USDA Forest Service (USFS) – amount to over one half of Oregon land ownership. Those same federal lands are mostly in the Cascade Range, central Oregon basin and range, and eastern Oregon, all areas of high geothermal potential.

Both competitive and noncompetitive leasing has occurred in Oregon for over 30 years, beginning in earnest in 1976. The first geothermal lease applications in Oregon began at Newberry volcano in 1974, one month after geothermal lease procedures for federal lands had been formalized. After a long hiatus, competitive federal leases were auctioned December 2008 for parcels at Glass Butte in Central Oregon. Two companies, Ormat Nevada and Magma Energy (US) bid on 11 parcels totaling over 41,000 acres.

Basin & Range Exploration

As early as 1978 the U.S. Geological Survey cited the Alvord Valley geothermal resource potential as among the highest in Oregon. Competitive leasing applications led to the creation of the Alvord KGRA (at that time, federal leases in KGRAs were only issued on a competitive basis). The northern portion of the valley is designated as Wilderness Study Area and is not open for development. Exploration for geothermal resources took place there and in the adjacent Pueblo Valley. Then, as now, environmental concerns, litigation, and administrative requirements impeded development. In 1993 at the Pueblo Valley, Anadarko Petroleum drilled and tested a 450m (1480 ft.) small diameter well. It flowed 1200 l/m (320 gpm) at 151°C (305°F) (Figure 7). In 1995, Anadarko submitted plans to supply, build, and operate a 23 MW (net) air-cooled binary power plant in Pueblo Valley. The project received intense opposition in the scoping phase of the environmental review (McClenahan, 2005). Anadarko negotiated at length with Portland General Electric and other private utilities but was unable to secure a power sales agreement. Between the opposition and lack of market, Anadarko abandoned the project shortly thereafter.
Cascade Range (Newberry) Exploration

The earliest documented commercial use of geothermal fluids at Newberry began in 1913 when a lease was issued to build and operate the East Lake Health Resort, subsequently closed in 1941. The first geothermal lease applications on Newberry were recorded in February 1974, one month after federal lands had formalized geothermal lease procedures. In 1976, the Newberry Known Geothermal Resource Area (KGRA) was created. In 1978, the US Geological Survey published the results of an assessment of geothermal resources within the US. The assessment estimates for sustained economically producible geothermal energy from Newberry Volcano as 740 MW for 30 years. Scientific drilling inside the caldera by the U.S. Geological Survey encountered 265°C (509°F) fluid. The 941 meter (3090 ft.) deep well was drilled in 1980. The drilling of this well was halted due to concern of the extreme rate of temperature increase that was being encountered.

Four deep exploration test wells have been completed on the upper northwestern flank of Newberry Volcano, two drilled by CE Exploration (CEE 23-22 and CEE 86-21) and two drilled by Davenport (NWG 46-16 and NWG 55-29). CE Exploration drilled in the mid 1990s to test the ring fracture system on the west side of the caldera. CE’s wells encountered a fresh granodiorite rock at bottom hole but limited porosity and sub-commercial production rates (McClain, 2009). Davenport drilled their wells in 2008. All four wells exhibited high bottom-hole temperatures, ranging from 290 – 330°C (550 – 625°F). Well 46-16 was opened for a flow test in conjunction with a passive seismic monitoring survey in September of 2013. The well discharged both gas and liquid through a 4” bleed line, coming in without any well stimulation. The well flowed on each of three tests (see photo below), confirming that Davenport Well 46-16 is a high-temperature geothermal discovery well (Waibel & Frome, 2014).

Well 46-16 is the only deep exploration well to have intersected hydrothermal fractures. It was drilled approximately 2 km WNW of 23-22, encountered thermally metamorphosed volcanic rock to a drilled depth of 11,600 ft., and had an estimated bottom-hole temperature in excess of 316°C (600°F). The well was located to explore a westerly-striking linear gravity boundary. This well is located within two miles of the caldera boundary, further outward of this boundary than the two California Energy Company deep exploration wells. This is the only deep exploration well to have encountered significant evidence (fig. 8) of a hydrothermal system. (Waibel & Frome, 2014).

The year 1984 saw two federal geothermal units created in Oregon, where before there were none. Units allow competing interests to work together and resources to be explored and developed efficiently. In January 1984 Cal Energy formally unitized approximately 99,000 acres of Winema National Forest land, state lands, and private lands into Mazama Unit Areas I & II (Figure 9).

These lands bordered Crater Lake National Park. In July 1984 the BLM approved a Union Oil application to unitize 24,000 acres...
of Deschutes National Forest land and 10,000 acres of private lands into the Black Butte Unit Area. Temperature gradient drilling took place at both units. At Mazama one well did identify a blind system that was above boiling, possibly 100°C (212°F) at about 366 m (1200 ft) (LaFleur, 2014). The site generated concern and some controversy at the Mazama unit, due to proximity to Oregon’s only National Park. Unit agreements and leases were subsequently dropped at both sites.

CalEnergy Co. took lease positions at several Oregon locations in the late 1980s. From that start the subsidiary CE Exploration proposed to build and operate a 33-MW geothermal power plant and supporting facilities on the west flank of Newberry Volcano. These facilities were to be located on Deschutes National Forest lands outside the Newberry National Volcanic Monument, created in 1990. The monument closed the caldera and other areas to further exploration. Lands outside the monument are generally open for development. The project was undertaken as part of BPA’s Geothermal Pilot Program started in 1991. Net power sales were to be sold to BPA and Eugene Water & Electric Board. It included a well-conceived and executed public involvement effort. Federal agencies approved the project in 1994. CE Exploration tested the ring fracture system on the west side of the caldera. CE’s wells encountered a fresh granodiorite rock at bottom hole but limited porosity and sub-commercial production rates (McClain, 2009). Davenport drilled four deeper test holes on the upper northwest flank of the volcano. Two of those holes were drilled as production test wells; hole 86-21 drilled to 2800 meters (9200 ft) and hole 23-22 drilled to 2926 m (9602 ft). Well 23-22 is reported to have had a bottom-hole temperature of 290°C (550°F). Well 86-21 is reported to have had a bottom-hole temperature of 315°C (600°F) (Waibel, 2009). Drilling results apparently convinced CE Exploration management and BPA to renegotiate terms and move the project to Glass Mountain California in 1996 (Pease, 2005), where a project did not ensue.

Eastern Oregon Exploration

Neal Hot Springs was first explored by Chevron in the 1970s but resources were insufficient for the available technology. A second BPA Geothermal Pilot Program project took place in the early 1990s at Vale, Oregon. It was to be 30 MW with BPA and partner Springfield Utility Board purchasing the power. TransPacific Geothermal drilled 17 shallow and two deep exploration wells before relinquishing federal leases due to their inability to confirm an economically viable resource. Parties to that agreement moved the project to Glass Mountain, Northern California in 1996 (Pease, 2005), where, again, a project did not materialize.

Current Development

Wildcat efforts aside, the discussion above illustrates three prudent, deliberate efforts to generate geothermal power at Pueblo Valley, Newberry Volcano and Vale, Oregon. Until 2009 Oregon experienced a period of geothermal exploration dormancy. Renewable (power) portfolio standards (RPS) came into effect in Oregon based on 2007 legislation. The law requires large private utilities to meet a portion of their loads with renewable energy sources, typically a ladder of percentages over time. For the state’s largest private utilities, it started at 5% in 2011 and ends with 25% by 2025 (ODOE, 2007). A strong RPS encouraged developers to pursue geothermal projects.

In contrast to portfolio standards are available standard power sales contracts. Renewable projects in Oregon under 10 MW in size can earn only $44 per MWh on-peak and $28/MWh off-peak currently (PP&L, 2014). Projects larger than 10 MW require negotiations with utilities. The Neal Hot Springs project has a contract with Idaho Power Corp. for over $90/MWh.

Power production today in Oregon occurs at three locations, Klamath Falls, Neal Hot Springs and Paisley Figure 10. Table 1 shows commercial operation dates and gross capacity on those plants.

<table>
<thead>
<tr>
<th>Date of Operation</th>
<th>Location</th>
<th>Developer</th>
<th>Gross MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-Nov-12</td>
<td>Neal HS</td>
<td>US Geo.</td>
<td>30.1</td>
</tr>
<tr>
<td>1-Jun-14</td>
<td>Paisley</td>
<td>SVEC</td>
<td>3.4</td>
</tr>
<tr>
<td>30-Apr-14</td>
<td>OIT</td>
<td>OIT</td>
<td>1.75</td>
</tr>
<tr>
<td>1-Apr-10</td>
<td>OIT</td>
<td>OIT</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>35.53</strong></td>
</tr>
</tbody>
</table>


In Klamath Falls the Oregon Institute of Technology is the first campus in the world that uses both heat and power from geothermal resources directly beneath the campus. A first 280 kW gross power plant using the 89°C (192°F) water was installed in February 2010 (fig. 11). The Pure Cycle© unit was supplied by United Technologies Corp. and interconnected to the grid in April of that year. Due to low power sales price (versus the retail price paid by the school) under net metering rules, power is used to meet about 10 percent of campus loads. Total costs for the first plant were $1,100,000 (Boyd & Lund, 2011).

A new 1.75 MW geothermal power plant was completed in May 2014. Both new and existing plants use organic rankine cycle technology. The second plant was supplied by Johnson Controls.
The school will meet its goal of supplying all energy needs with geothermal heating, geothermal power and solar power.

Neal Hot Springs is located 23 km (14 mi.) northwest of Vale. U.S. Geothermal Inc. developed the 22 MW net Neal Hot Springs project. Geophysical work was completed and the first production well, NHS-1, drilled in 2008. Well NHS-1 yielded temperatures of 141°C (287°F) at a peak rate of 2,055 gpm (7800 l/m). The Neal Hot Springs project deployed a first of its kind binary cycle process, utilizing a supercritical cycle that uses R134a refrigerant as the working fluid, as well as pre-fabricated modular construction of major plant components (Figure 12). The project was built in three 7.3-megawatt binary cycle modules by Turbine Air Systems.

U.S. Geothermal engaged its power purchaser, Idaho Power Company, for the design and construction of the transmission line and substation from the Neal Hot Springs project site to Idaho Power’s nearby transmission grid. The new 16 km (10 mi) line is designed for 36 megawatts of transmission capacity and is estimated to cost $3.2 million. Additional wells and reservoir testing is needed before the size and power generation potential of the Neal Hot Springs geothermal reservoir can be determined.

Exploration for geothermal resources capable of generating power is taking place today at Newberry volcano, Crump Geyser, Klamath basin. These sites may have as much potential as 200 MW. By the time of presentation in September 2014 four plants at three sites will be fully operating. Table 2 below lists the sites, with the authors very conservative estimates of near term economic potential.

Newberry: CE Exploration proposed to build and operate a 33-MW geothermal power plant and supporting facilities on the west flank of Newberry Volcano. These facilities were to be located on Deschutes National Forest lands outside the Newberry National Volcanic Monument, created in 1990. The monument closed the caldera and other areas to further exploration. Lands outside the monument are generally open for development. The project was undertaken as part of BPA’s Geothermal Pilot Program started in 1991. Net power sales were to be sold to BPA and Eugene Water & Electric Board. It included a well- conceived and executed public involvement effort. Federal agencies approved the project in 1994. Drilling results apparently convinced CE Exploration management and BPA to renegotiate terms and move the project to Glass Mountain California in 1996 (Pease, 2005), where a project did not ensue.
Davenport Power In 2010 was awarded a $5 million DOE matching grant for the “Validation of Innovative Exploration Technology”. Also that year, Davenport with technology partner AltaRock Energy began using a $21.4 million DOE matching grant for the stimulation and demonstration of an EGS reservoir. Analysis of the 2012 stimulation results indicated that further stimulation of the reservoir would be needed to ensure the reservoir is large enough to be economically viable. In 2014 AltaRock plans to re-stimulate to increase the size of the deep reservoir and continue real-time seismic monitoring (Newberry EGS, 2014). Much information on the Altarock Newberry Enhanced Geothermal Systems Demonstration project is presented elsewhere in the 2014 Proceedings and on the Newberry EGS.

**Table 2. Oregon Geothermal Power Prospects 2014.**

<table>
<thead>
<tr>
<th>Site</th>
<th>Potential/Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newberry</td>
<td>120</td>
</tr>
<tr>
<td>Crump</td>
<td>20</td>
</tr>
<tr>
<td>Neal (exp.)</td>
<td>10</td>
</tr>
<tr>
<td>Vale</td>
<td>10</td>
</tr>
<tr>
<td>Klamath Falls</td>
<td>10</td>
</tr>
<tr>
<td>Paisley (exp.)</td>
<td>10</td>
</tr>
<tr>
<td>Glass Buttes</td>
<td>?</td>
</tr>
<tr>
<td>Mt Hood NF leases</td>
<td>?</td>
</tr>
<tr>
<td>Willamette NF leases</td>
<td>?</td>
</tr>
<tr>
<td>Total</td>
<td>140+</td>
</tr>
</tbody>
</table>

Ormat and Alternative Earth Resources through joint venture Crump Geothermal Company are developing leases on private land at Crump “Geyser” in the Warner Valley 50km (30mi) east of Lakeview. Geophysical studies and drilling of three exploration wells has occurred. These wells targeted faults on the east front of the Warner Mountains and intersected 265°F (130°C) thermal waters. (Alternative Earth Resources, 2014). Further drilling is planned to explore for potential higher temperature resources (300°F [150°C]) in the basin. Project feasibility studies, testing and reservoir confirmation are underway. The project is for up to 20 MW, expected to be placed in service gradually.

East of Klamath Falls in 2011, OM Power 1 LLC driled Olene Gap well #3, a vertical prospect well with promising results. South of Klamath Falls, Klamath Basin Geopower is exploring the potential for a power plant on 2,500 leased acres near Olene. The company would like to develop a 20 megawatt power plant.

Ormat is continuing geophysical exploration at Glass Butte in Central Oregon. Other sites include long-time federal lease applications in the Cascades for which the potential in unknown.

**Conclusion**

Geothermal power development took off in Oregon beginning in 2010. Klamath Falls continues its steady growth, both in direct use and now power generation. Exploration is returning to sites explored 50 years ago at Warner Valley and 40 years ago at Glass Butte. Much of what was recently built is relatively small and on private land, two key factors. Those along with genuine interest from power companies both in and out of Oregon are motivating development. The author is optimistic that with several power plants operating, more high-temperature prospects will materialize into modest power plants. Oregon’s existing power plants prove geothermal power viability in an environmentally sensitive land with less expensive alternatives. It is a modest but solid beginning.

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