OPTIONS AND QUESTIONS FOR DIRECT USE IN PUNA, HAWAII

Andrea T. Gill
Dept. of Business, Economic Development and Tourism
Strategic Industries Division
State of Hawaii

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ABSTRACT

Several options for the development of geothermal direct use enterprises in Puna, Hawaii have been identified, including: 1) tapping waste heat from the Puna Geothermal Venture (PGV) power plant; 2) extracting heat from unused, existing exploratory wells; and 3) drilling new shallow wells to the top of the aquifer. Shallow (less than 305 meters deep) wells drilled in Puna during exploration for both potable water and geothermal resources indicate a low-temperature resource near the top of the aquifer, at or near sea level. However, PGV is currently injecting waste fluids at 150° C; waste heat from this source could be made available for direct utilization, obviating the need for new production or injection wells. Several scenarios for developing heat for direct uses are explored, along with their regulatory ramifications. Unanswered questions relating to the application of State and County laws and regulations are noted.

INTRODUCTION

Hawaii, unlike most other Western states, has less experience with the direct use of geothermal heat than with geothermal electricity. Apart from the continuing traditional uses of swimming and soaking in warm springs along the coast and enjoying natural steam vents as saunas, the only documented direct uses of geothermal heat were small experiments in the late 1980s known as the Community Geothermal Technology Program (Beck, 1989).

In contrast, Hawaii's experience in geothermal exploration for electricity generation dates back at least to the 1960s. Geothermal exploration by several different companies and landowners eventually resulted in the successful establishment of a 30-MW power plant by Puna Geothermal Venture (PGV), which became fully operational in 1993.

During the last four and a half decades, a number of wells have been drilled in and near the Kilauea East Rift Zone (KERZ) for various purposes (see Figure 1). Their temperatures, depths, and water chemistry provide insight into the geology of the rift zone and the nature of geothermal resources in the Puna District of the Island of Hawaii. This information is proving valuable as interest in non-electric uses of geothermal energy increases.

The Hawaii County Geothermal Direct Use Working Group drafted this map depicting wells in the Puna District near the current geothermal development area. These wells, both deep and shallow, were drilled for a variety of purposes and provide insight into the resources that could support direct use.

SHALLOW EXPLORATORY WELLS

Shallow wells for both potable water and geothermal power production have been drilled at several dozen sites in the lower Puna area from near the town of Pahoa to the easternmost point of the island, Cape Kumukahi. In this context, "shallow" generally means depths of less than 305 meters (1,000 ft), usually to the top of the aquifer. This water may or may not be hot, and may or may not be potable.

The chemistry of fluids tapped by the shallow wells is quite different from those tapped by the deep wells drilled for geothermal production. The Hawaiian Islands' highly fractured subsurface basalts allow seawater to penetrate deep within the interior structure of the volcanic masses. Meteoric water percolates through the permeable soil and fractured rock until it encounters seawater; this less-dense fresh water then forms a Ghyben-Herzberg lens, floating on top of the seawater. In the coastal areas, the fresh water aquifer is fairly thin, encountered near or at sea level.

This basal water is encountered both north and south of the KERZ. Within the KERZ, however, fresh water is considered both dike-confined and dike-controlled (Iovenitti, 1990). The dike system within the rift provides both a source of heat and a leaky boundary which controls the hydrology of the geothermal system; dikes and possibly mineral deposition from seawater help exclude saline fluids from deeper portions of the rift and partially isolate the groundwater within the rift from the larger groundwater flow system (Thomas, 1985 and Scholl, 1993).

Magma sources heat both the meteoric water and the seawater that has infiltrated the island mass; in places, the heated water rises to the top of the aquifer. Water chemistry data show mixing of seawater and meteoric water in a large thermal system south of the KERZ (Janik, 1994).

Shallow wells near the coast, which tap the top of the aquifer, may thus encounter a buoyant layer of warmed, somewhat saline water. If these wells were drilled slightly deeper, they would probably penetrate through the warmed layer, encountering reduced temperatures. Although the KERZ structure is complex, with many fractures and intrusive structures which can either enhance or limit fluid circulation, in general wells deeper than 1,000 meters are required if a high-temperature resource is being sought.

In 1961, a major landowner in the Puna District of the Island of Hawaii drilled four shallow exploratory geothermal wells. Dubbed Puna Thermal TH1 through TH4, these wells were drilled to depths ranging from 66 meters to 210 meters and encountered fluid temperatures ranging from 43° to 95° C near the top of the aquifer. These temperatures are too low for viable electricity production, and deeper wells were not considered at that time. These wells remain unutilized.

A number of shallow wells have also been drilled by both public and private entities to locate potable water resources. Current potable water wells are located north and west of the geothermal production area, outside of the KERZ. With depths ranging from approximately 130 meters to 245 meters, these wells penetrate roughly 20 meters below mean sea level and produce potable water between 20° and 25° C.

Other water exploration wells were drilled in Puna, some within the KERZ or just outside its approximate boundaries. With depths ranging from 14 to 102 meters, extending from three to 30 meters below mean sea level, these wells show evidence of seawater intrusion and are considered too saline for the municipal water supply. In addition, several wells' temperatures were elevated, with the warmest at 56° C. Most of these nonpotable water exploration wells are currently unused, though one serves as a backup water quality monitoring well for PGV's operations.

DEEP GEOTHERMAL EXPLORATION AND PRODUCTION WELLS

As the geothermal industry matured, deeper wells were drilled. Within the KERZ, the first successful deep geothermal well was the public HGP-A well that provided steam for a demonstration 3-MW power plant and encouraged private exploration. HGP-A was completed in 1976 to a depth of 1,967 meters, achieving temperatures of 360° C. When private developers encountered a producible resource nearby with wells drilled in the 1980s, HGP-A's usefulness as a demonstration came to an end. The well was permanently sealed in 1989.

Most of the 19 deep geothermal wells completed in the 1980s and '90s were drilled for geothermal exploration and production, although three were scientific observation holes used to gather information on the subsurface geology in the KERZ. Temperatures ranging from 220° C to over 350° C were recorded in the deep wells. Not all of these wells were producible, however, and many have been plugged.

Most major productive zones lie 1,219 to 2,134 meters (4,000 to 7,000 ft) below the ground surface (GeothermEx, 1994). The depths of most of the deep wells range from approximately 1,400 meters to over 2,500 meters. Their mean depth below sea level is 1,829 meters, although two wells, KS7 and KS8, encountered pressurized, hot fluids at comparatively shallow depths (KS8 reached a depth of 1,060 meters, 868 meters below mean sea level). These two wells are among those that have been plugged.

Two new wells are being drilled in mid-2005 by PGV. KS6 is intended to be a fourth production well for the power plant, and KS13 is expected to serve as a fourth injection well.

REGULATORY FRAMEWORK FOR DIRECT USE

The State of Hawaii anticipated non-electric uses of geothermal heat when establishing statutes and regulations in the 1980s. State law relaxes some regulatory requirements if geothermal heat is to be used directly. For instance:

Subzones: State land use laws specify appropriate uses in broad categories of land, including urban, rural, agricultural and conservation. In addition, special geothermal "subzones" were created. According to Hawaii Revised Statutes (HRS) Section 205-5.1, exploration and development of geothermal resources for electricity production can only occur in these four subzones, three of which are in the KERZ. Non-electric applications, however, are only limited to a geothermal subzone if the land is zoned for conservation purposes.

Definition of a geothermal resource: State law (HRS Section 182-1) defines a "geothermal resource" as having temperatures above 150° F. Lower temperature fluids, then, are not regulated as geothermal resources, and users of lower temperature fluids need not obtain State geothermal exploration or well drilling permits. However, wells drilled to tap geothermal fluids of 150° F or less must still be permitted as water wells by the State Commission on Water Resources. The permitting process is outlined at the Commission's website (http://hawaii.gov/dlnr/cwrm/). A permit is necessary even if the water is expected to be nonpotable (Nakano, pers. comm., 2005). In addition, the disposal of fluids is still governed by Federal Environmental Protection Agency (EPA) and State Department of Health rules on underground injection.

Despite having reduced regulatory requirements at the State level, developers of geothermal direct use projects will be breaking new ground, both figuratively and literally, since no one has yet permitted a direct use operation in Hawaii. The exact application of State and County laws and regulations has yet to be exercised.

Currently, the County of Hawaii issues a Geothermal Resource Permit for "geothermal development activities," including both research and commercial activities and meaning "exploration, development, or production of electrical energy from geothermal resources, or as otherwise defined in Hawaii Revised Statutes (HRS), Section 205-5.1."

Since the language in the County's Rule 12, Geothermal Resource Permits, specifically refers to the production of electrical energy, and since the referenced HRS Section 205-5.1 relates to geothermal resource subzones and includes the exemptions for direct use applications mentioned above, it is not unreasonable to assume that County permitting will comport with State permitting. However, County Planning Department staff opinion has not been rendered on the subject. Thus, potential County regulation of direct use development remains an unknown factor in developing non-electric uses of geothermal energy.

DIRECT USE RESOURCE OPTIONS

The County of Hawaii, supported by the State of Hawaii Department of Business, Economic Development and Tourism with funding from the U.S. Department of Energy, is investigating potential non-electric uses of geothermal heat in Puna. As part of this effort, a Working Group has been formed to solicit comments and suggestions from the community, and a feasibility study will be performed. The funding does not include any implementation, such as drilling, experimentation or construction (Gill, 2004).

In discussions to date, several options for the development of geothermal direct use enterprises have been identified, including:

1) Tapping waste heat from Puna Geothermal Venture's power plant;
2) Extracting heat from unused, existing exploratory wells; and
3) Drilling new shallow wells to the top of the aquifer.

These options, and some of the questions they raise, will be explored briefly.

WASTE HEAT FROM PUNA GEOTHERMAL VENTURE (PGV)

PGV currently injects 3,000 gpm of fluids at or above 148° C (300° F) after power production (Mizuno, pers. comm., 2005). The company is amenable to providing waste heat for non-electric purposes, as long as its power plant operations are not negatively affected and terms of its current lease and permit are adhered to. One critical permit requirement is that geothermal fluids produced by PGV must be injected by PGV within their lease area. This precludes export of the fluid itself beyond the lease boundaries. However, extracting heat via a heat exchanger is a technically viable option, and water—presumably from a potable public supply—thus heated could be piped beyond the boundaries of PGV's lease.

The heat exchanger itself would be a critical component of such a system and must be suitable for the chemistry and temperatures of the geothermal fluid. The geothermal brine injected by PGV averages 127 mg/l Si02 and 539 mg/l H2S (GeothermEx, 1994). Maintenance of the heat exchanger in view of the potential for precipitation and deposition of dissolved solids will be essential.

Although County regulators have not yet thoroughly considered the ramifications of such an export of heat from PGV, company officials believe that this activity would be allowed under its current permit. Assuming this is true, direct use applications would be spared the expensive, regulated activities of drilling new production and injection wells. A high temperature resource would be available without further exploration.

Waste fluids from PGV's operations are considerably hotter than those that have historically been tapped by shallow wells, allowing a broad range of non-electric uses. Further, PGV has indicated that the heat would be available at no cost (Mizuno, pers. comm., 2004). A third party, however, would need to invest in the infrastructure—a heat exchanger, pipes, and circulation pump, for instance—to extract the heat and transfer the hot water to the location where it would be used. The capital cost of this equipment will be estimated during the feasibility study phase of the State and County's direct use project.

Another task of the feasibility study will be to identify a suitable location for direct use enterprises utilizing waste heat from PGV. The company prefers such activities to be sited outside of their 800-acre lease (Mizuno, pers. comm., 2004). Adjoining properties are generally zoned for agricultural purposes, which would allow enterprises such as fruit dehydration and growing media pasteurization.

One possible location is the four-acre Noii O Puna laboratory site adjacent to PGV's lease. Previously the location of the HGP-A well and power plant, this was also where the Community Geothermal Technology Program direct use experiments were performed. Should Noii O Puna be refurbished for geothermal direct use enterprises, its size may limit its desirability for some applications, such as extensive greenhousing.

WARM WATER FROM UNUSED, EXISTING WELLS

There are more than a dozen shallow wells in or near the KERZ, some of which indicate elevated temperatures. PGV's three monitoring wells, for instance, have temperatures ranging from 44° to 67° C.

The highest temperature recorded in a shallow exploratory well is 95° C, in TH3, one of the wildcat wells drilled in 1961. Located on private agricultural land east of PGV's facility, its condition and suitability for use are unknown.

One of the existing shallow wells, Malama Ki, is owned by the University of Hawaii (UH) and located on a UH agricultural experiment station south of PGV, approximately two miles inland from the eastern Puna coast. Although the maximum recorded temperature, 56° C, is fairly low for most purposes, the existence of the well has raised some interest among UH agriculturalists. Among the applications suggested are aquaculture and pre-export soil disinfestation of potted plants.

The State of Hawaii Department of Land and Natural Resources (DLNR) drilled the Malama Ki well in 1962 in an effort to identify potable water supplies. Although the water is not potable, the well was used for monitoring through the mid-1990s and is presently considered a standby monitoring well for PGV. Water chemistry data have been published by the U.S. Geological Survey (USGS) (Janik, 1994), among others.

The ground surface elevation at Malama Ki's wellhead is 83.5 meters and the well itself is 97.2 meters deep. Static water level is between 0.56 and 0.86 feet above mean sea level. The bottom 14.6 meters (48 ft) of the eight-inch casing is perforated (State of Hawaii, 1962). The pumping test rate was 480 gpm, and temperatures during the test ranged from 53° C (127.5° F) to 54.7°C (130.5°F). Malama Ki's chloride content ranged from 3,811 to 6,887 mg/l during monitoring by the USGS (Janik, 1994). The well, which was percussion drilled, is covered by a removable metal lid. The status of the casing at depth is unknown, though surface oxidation is evident in the exposed portion.

Because it is located within the Malama Ki UH agricultural experiment station, the well, if utilized, must be used for agricultural purposes. The station itself has no utility power, public water systems, or telephone service. The 189-acre Malama Ki station was previously used extensively for species trials and is still home to a wide variety of tropical fruit and nut trees, including cacao, macadamia, guava, sapodilla, mangosteen, avocado, mango, papaya and lychee. Presently, USGS scientists use the old administration building as a camping headquarters during their field research on bird species.

Tapping the Malama Ki well for direct use poses a number of challenges. First, the condition of the well and casing are not known, nor the long-term sustainability of temperature levels if the well is produced.

If the hot groundwater were to be pumped to the surface for direct use, a power supply for the pump would be needed. Power for a pump would either require a new utility line or an independent power system, such as one based on photovoltaics; both options are likely to be discouragingly expensive.

Water brought to the surface will eventually need to be disposed of. Normally, the State of Hawaii Department of Health and the EPA require injection wells to protect the aquifer.

Another option for withdrawing heat with reduced pumping costs is a downhole heat exchanger (DHE). The eight-inch diameter of the existing casing would allow the use of DHE. However, the casing is probably not undersized relative to the well wall; that is, there is probably not an annulus between the casing and the well wall which would promote the formation of a convective cell necessary for good DHE performance.

One alternative might be the use of a convection promoter pipe (CPP). A CPP, usually perforated at the top and bottom and inserted into a cased well, creates a pathway that establishes one-cell thermal convection as long as reasonable permeability exists at the well bottom. The presence of a CPP with a DHE has improved the heat output of the DHE by 60% to 120% in laboratory experiments, and demonstrations at Taupo, New Zealand, have also been successful (Allis, 1980). It is possible that a 6-inch diameter plastic pipe, into which a 2-inch DHE is inserted, would be sufficient to withdraw useable heat (Culver, pers. comm., 2005).

It should be noted that geothermal DHE systems are typically used for domestic water and space heating, not for agricultural applications, and their potential heat output is less than that of pumped wells.

A DHE would need a source of water to circulate within the system, picking up heat from the well. Currently, there is no water supply in the Malama Ki station except for some large storage cisterns near the old office buildings.

Further, the resource temperature encountered by the Malama Ki well is already fairly low, 56° C. This would be reduced further by losses at the heat exchanger, limiting the types of direct use applications that could be supported. Among the low-temperature uses that might still be viable are aquaculture and greenhouse bottom heating.

On the positive side, however, a pump to circulate water through the DHE often requires only a fraction of a horsepower, an order of magnitude less than that needed to pump water out of the well. It may be feasible to supply this amount of electricity with photovoltaics. Furthermore, in some DHE applications, natural convection alone is sufficient to circulate the working fluid without a pump. A DHE would also make fluid disposal unnecessary, since no geothermal water would be brought to the surface.

DRILLING NEW, DEDICATED SHALLOW WELLS FOR DIRECT USE

The third option for developing geothermal direct uses in Puna is, of course, drilling new wells exclusively for non-electric purposes. Temperatures attained by existing shallow wells indicate that water hot enough for a variety of applications may be tapped at the top of the Puna aquifer; that is, at roughly sea level. The surface elevation near PGV’s operations is around 183 meters (600 ft), and declines to zero to the east. The depth of a new well would be dictated primarily by the elevation of the wellhead.

Costs for drilling, casing and testing exploratory water wells, 16-20 inches in diameter, currently range from $600 to $700 per foot. If the well is to be produced, the pump, motor, piping, fittings, buildings, etc. can add another $1,000 to $1,200 per foot (Young, pers. comm., 2005). Therefore, a new well in the general vicinity of PGV, where shallow wells such as TH3 and MW2 have encountered temperatures between 67° and 95° C (153° and 203° F), might cost $1,000,000. However, note that a well tapping temperatures above 150° F would be considered a geothermal well rather than a water well by State regulations; equipment such as for blowout prevention would increase costs. An injection well for the spent fluid would be an additional expense.

As in any other geothermal operation, of course, there is no guarantee that sufficiently hot water would be encountered at shallow depths. Several miles north and east of PGV, two wells—Kapoho Airstrip and SOH2—were drilled within a few hundred feet of each other. The deep Scientific Observation Hole #2 (SOH2), which extended to a depth of 2,073 meters, attained temperatures of 350° C (Olson, 1993). However, the adjacent shallow exploratory water well, Kapoho Airstrip, is only 102 meters deep. The highest recorded temperature was only 38° C (Janik, 1994).

A third well, TH4, which is east of SOH2 and the Kapoho Airstrip well, was only 88 meters deep and recorded temperatures of 43° C.

Since the State DLNR's regulations have never been applied to direct use, there is some question as to how the temperature limitation of 150° F will be interpreted. Is it to be measured at the bottom of the hole? If the well is permitted as a water well, not a geothermal well, and unexpectedly encounters temperatures above 150° F, what procedures would need to be followed? Would the developer then need to apply for a Geothermal Exploration Permit and a Geothermal Well Drilling Permit? Would additional equipment, such as blowout prevention, then need to be acquired, unexpectedly increasing costs? Would the additional expenses and delays make direct uses economically unviable?

These and the other unanswered questions listed above will be addressed as the County/State geothermal direct use project continues.

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