Hawaii Renewable Energy Development Venture (HREDV) Program
Assessment of Technology Readiness and Applicability -
Low Grade Geothermal Heat

1. Overview:

The focus of this assessment is the use of low grade, or low temperature, geothermal heat for renewable energy applications in Hawaii.

Geothermal energy is currently used in Hawaii as a renewable energy resource for electricity generation on the Big Island of Hawaii. Puna Geothermal Venture (PGV) currently provides up to 30 MW of power to the Hawaii Electric Light Company (HELCO) utility grid. The geothermal resource in the area of the commercial operation is notable as a high temperature resource, with recorded temperatures in excess of 360°C (685°F). (GeothermEx, 2000) While Hawaii has had decades of experience with production of electricity from this high temperature resource, its experience with use of the resource at lower temperatures has been limited.

Geothermal resources are classified as low temperature if less than 90°C (194°F), moderate temperature if in the range of 90°C - 150°C (194 - 302°F), and high temperature if greater than 150°C (302°F). (GHC, 2009) While the highest temperature resources are used for electric power generation as on the Big Island, low and moderate temperature resources are used for direct use applications and ground-source heat pumps (GSHP).

It should be also noted that moderate temperature geothermal resources can be used for electricity generation in binary-cycle power plants whereby a heat exchanger is used to transfer heat to a secondary working fluid. The Chena Hot Springs Power Plant, for example, uses geothermal fluids from Chena Hot Springs at 165°F, the lowest temperature geothermal resource to be used for commercial power production in the world. The plant's technology, developed by UTC, can operate using any heat source with a minimum of 100°F temperature differential between the heat source and sink. (Chena, 2009) With identification of appropriate geothermal resources and heat sink, power generation using a moderate temperature resource in Hawaii may be technically feasible using innovative technology such as that used at Chena Hot Springs.

Direct Use Applications

Direct use applications typically include the use of geothermally heated water for heating of buildings, industrial processes, greenhouses, aquaculture and resorts. Direct use projects generally use resource temperatures between 38°C (100°F) to 149°C (300°F). Current U.S. installed capacity of direct use systems totals 470 MW or enough to heat 40,000 average-sized houses. (GHC, 2009) Lower temperature geothermal fluids from geothermal electric plant operations can also be used for direct use applications in "cascaded" applications. (USDOE GTP, 2009)

In 2007, Okahara and Associates completed a feasibility study for direct use applications in the Kapoho/Pohoiki area of the Big Island (near the PGV plant) to determine the technical and economic feasibility of geothermal direct use applications, focusing on four agriculture-related businesses for a hypothetical 15-acre geothermal enterprise park. The study concluded that "geothermal direct use in the Kapoho/Pohoiki area is marginally feasible at best. Significant subsidies on the order of $9.2 million are needed to ensure economic feasibility, a stable source of heat from a future high temperature geothermal application business needs to be identified, and legislative changes may need to be made before direct use can become a reality." The study was conducted for the State Department of Business, Economic Development and Tourism under a grant from the US Department of Energy. (Okahara, 2007)

The Okahara study could not confirm the feasibility of direct use in an area identified as promising due to its known geothermal resource, available land, and agriculture base. Based on this study, it is apparent that the feasibility of direct use in other areas of the state should similarly be investigated in advance of any project planning. The focus of this analysis of the potential use of Hawaii's low temperature geothermal resource will therefore be ground source heat pump technologies.

Ground Source Heat Pump Technology

Ground Source Heat Pumps (GSHP), sometimes called Geothermal Heat Pumps or "geoexchange", use heat from the earth, or groundwater, typically as a heat source in winter and a heat sink in summer. The source of heat may be geothermal or solar. A GSHP uses resource temperatures of 4°C (40°F) to 38°C (100°F) to transfer heat from the soil to a building in winter and from the building to the soil in summer boosting efficiency and reducing operational costs of heating and cooling systems. The technology is commercially well-established for commercial and residential use with the rate of installation estimated to be between 10,000 and 40,000 per year. (GHC, 2009)

A GSHP system typically includes three primary components – a ground loop, a heat pump, and a heating and cooling distribution system. There are four basic types of ground loop systems. Three of these—horizontal, vertical, and pond/lake—are closed-loop, and the fourth is open-loop. These various loop systems can be used for residential and commercial building applications, however, selection is dependent on climate, soil conditions, available land, and installation costs. The types of ground loop systems are as follows:

- Horizontal (closed loop) -- This type of installation is generally most cost-effective for new residential construction where sufficient land is available.
- Vertical (closed loop) -- Large commercial buildings and schools often use vertical systems where the land area required for horizontal loops would be prohibitive.
- Pond/Lake (closed loop) -- If an installation site has an adequate water body, this may be the lowest cost option.

- Open-Loop -- This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the GHP system. (USDOE ES, 2009)

A U.S. Environmental Protection Agency study of all residential heating, cooling, and water-heating systems concluded that GSHPs 1) can reduce energy consumption and related emissions by 23% - 44% in comparison to air-source heat pumps, 2) generally have lower carbon dioxide emissions than conventional equipment, and 3) have the lowest annual operating costs of all conventional technologies, as well as competitive lie-cycle costs. (USDOE FEMP, 2009)

2. **Status of commercial readiness:**
The GSHP technology is commercially well-established for commercial and residential use with the rate of installation estimated to be between 10,000 and 40,000 per year. (GHC, 2009). The U.S. Department of Energy's Federal Energy Management Program estimates that there are more than 400,000 GSHP systems installed in the U.S. The federal government has installed almost 10,000 systems. (USDOE FEMP, 2009)

3. **Appropriateness to Hawaii**
The efficiency and energy savings that result from the use of GSHP technology on the Mainland and other locations worldwide can be significant, including both heating during the winter and cooling during the summer. Due to Hawaii's moderate climate, the benefits may not be as significant as with systems installed where climate changes are more extreme. Although a typical system installation may be replicable in Hawaii, GSHP systems have not been used in Hawaii (although anecdotally, some installations may exist). Neither has there been a publicly funded study of potential Hawaii applications, thus the economic feasibility of GSHP installations cannot be certain. However, it is technically possible that there are conditions where geothermally or solar-heated ground or water may provide heat for buildings in cooler microclimates in Hawaii, or there may be applications where a GSHP system may serve as a heat sink to increase efficiency of space conditioning.

The promise of GSHP technologies for Hawaii applications may be in their use in hybrid systems, particularly as a means to innovate HVAC (heating, ventilation, and air conditioning) design. A hybrid GSHP HVAC system, for example, was installed at a Florida beachfront hotel challenged with climate and cost conditions similar to those of Hawaii.

The project, in Pensacola, Florida, was recognized in 2008 by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) with a first place Technology Award for the GSHP installation. The project involved hot and humid conditions, and salt-laden atmosphere. Constrained by high land, water, and sewer costs, the system was designed with a smaller footprint and without a conventional open cooling tower, minimizing water consumption. Due to a restricted loop field area, a closed-loop evaporative fluid cooler supplemented the ground loop field. The hybrid system serves space conditioning, water heating, pool and spa heating, and ice machine requirements.

The system has demonstrated low maintenance cost, high energy efficiency, reduced water consumption, and consistent performance. Life-cycle costs are anticipated to be reduced with fewer of the system components exposed to the salt environment. Ground loop life expectancy is estimated to be over 50 years. Overall annual energy intensity for the hotel is 37 percent below the 1995 Commercial Building Energy Consumption Survey intensity for the lodging segment national average. Additionally, initial system cost was less than a HVAC system with central plant chiller and boiler. (Barfield, 2008)

How will the technology help in the introduction of renewables into the Hawaii energy system?
GSHP systems that use a geothermal resource are considered renewable energy systems.
It is uncertain whether systems that do not use a geothermal resource would also be considered as renewable energy systems. However, it may be feasible to couple a renewable energy generation system, such as solar PV, to the GSHP system to provide power for its operation.

The use of a GSHP also can decrease the building load, as described in the Florida hotel project example above, such that renewable generation systems have a larger role in total building electricity generation.

Is this a technology that is a key to success in other areas (cross cutting)?
The effectiveness and feasibility of the technology has been proven under Florida's resort industry conditions, in many ways similar to Hawaii. Use of the technology in HVAC systems may increase total system efficiency and lower life-cycle costs.

4. Considerations related to specific technologies and/or resources

Due to Hawaii's high land costs and limited land area, it is likely that the cost of land-based installations, whether horizontal or vertical, will be high. Installations that use water as a heat sink could be considered.

5. References

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