COUNTY OF HAWAII
DEPARTMENT OF RESEARCH AND DEVELOPMENT
HILO, HAWAII

FEASIBILITY STUDY

GEOTHERMAL DIRECT USE
Kapoho / Pohoiki Area

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EXECUTIVE SUMMARY

Geothermal heat has been widely used for both electric and non-electric (direct) purposes throughout the world for years and Hawaii is no exception. Puna Geothermal Venture's 30-megawatt power plant currently supplies approximately 20% of the Island of Hawaii's electricity demands. However, with the exception of a few natural hot springs and steam vents used for personal use and small commercial ventures in the Puna area, Hawaii does not take advantage of geothermal heat for direct uses.

The purpose of this study was to determine the feasibility of developing direct uses of geothermal heat in the Kapoho / Pohoiki area of Puna on the Island of Hawaii. The feasibility study found that geothermal direct use is technically feasible but only marginally economically feasible.

The study identified four potentially viable geothermal direct use enterprises and nine additional community-friendly geothermal direct use enterprises. The four most promising geothermal direct use enterprises include greenhouses, pasteurization of potting media, biodiesel production, and lumber kilns.

The study found the only potential viable sources of heat in the Kapoho / Pohoiki area were Puna Geothermal Venture (PGV) and some future high temperature geothermal application. It was determined acquiring waste heat from PGV is unlikely because of planned power plant modifications. Therefore, the only potential viable access to geothermal heat would be through a future geothermal development.

A hypothetical 15-acre geothermal direct use enterprise park with a mixed use of tenants and with a source of heat from a future high-temperature geothermal business similar to PGV was analyzed. It will cost approximately $12.5 million to develop and construct, and $738,000 to operate and maintain a 15-acre geothermal direct use enterprise park in the Kapoho / Pohoiki area. Annual revenue is expected

to be $1.21 million based on a lease rate of $200/acre-year and a geothermal heat rate priced at $1.32 per therm (100,000 Btu), a 50% discount of the prevailing average fuel rate of diesel and propane. The anticipated payback period for the project is 26 years without financial subsidies, and 7 years with $9.2 million in financial subsidies.

The economic impact of a 15-acre geothermal direct use enterprise park on the Kapoho / Pohoiki community will depend on the amount of investment into each geothermal direct use enterprise. An equal investment of $500,000 each into greenhouse bottom heating, lumber kiln, sterilization of potting media, biodiesel production, and a university research facility would result in $9.2 million in additional sales, 130 new jobs, and $380,000 in additional taxes. Further, these activities would save approximately 8,000 barrels of crude oil per year at this scale of operation.

In conclusion, geothermal direct use in the Kapoho / Pohoiki area is presently marginally feasible. To create a successful geothermal direct use program, significant financial subsidies are needed to ensure economic feasibility; a stable source of heat from a future high temperature geothermal application needs to be identified; and legislative changes may be needed to redirect current County Geothermal Asset and Geothermal Relocation Program funds.

Should it become a reality, geothermal direct use could have a positive impact on the Kapoho / Pohoiki community by supporting existing agricultural industries, promoting diversified agriculture, creating jobs, and reducing dependence on fossil fuels.

CHAPTER 1 – INTRODUCTION

1.1 GENERAL – PROJECT INTENT

Geothermal heat has been widely used for both electric and non-electric (direct) uses throughout the world for some time. Hawaii is no exception. Puna Geothermal Venture's (PGV) 30 megawatt power plant became fully operational in 1993 and currently supplies approximately 20% of the Island of Hawaii's electricity demands. However, with the exception of a few natural hot springs and steam vents used for personal use and small commercial ventures in the Puna area, Hawaii does not take advantage of geothermal heat for direct uses.

The purpose of this study is to determine the feasibility of developing direct uses of geothermal heat in the Kapoho / Pohoiki area of Puna on the Island of Hawaii.

This study is Part 2 of a larger effort by the County of Hawaii Department of Research and Development (County) in cooperation with the Hawaii State Department of Business, Economic Development and Tourism (DBEDT) and the U.S. Department of Energy (DOE) to develop direct uses of geothermal heat. It is hoped that geothermal direct use can be found technically and economically feasible in the Kapoho / Pohoiki area and will lead to the development of a geothermal enterprise park for the benefit of the Puna communities.

Part 1 of the County's efforts consisted of establishing a working group to support direct uses of geothermal heat, providing information on direct use of geothermal heat to the community, and soliciting community opinion related to acceptable direct uses of geothermal heat. The results of Part 1 conducted between October 1, 2004 and September 30, 2005 may be found in the *Geopowering The West Program, Final Report*, September 2005.

Part 2 of the County's efforts is to determine the feasibility of developing direct uses of geothermal heat in the Kapoho / Pohoiki area of Puna on the Island of Hawaii.

Part 3 of the County's efforts will be to either develop or assist a private developer in the construction of a geothermal direct use enterprise park.

1.2 FEASIBILITY STUDY OBJECTIVES

This feasibility study investigated the following objectives in determining whether direct use of geothermal heat is feasible in the Kapoho / Pohoiki area of Puna on the Island of Hawaii.

1. Identify geothermal direct use enterprises that are likely to be commercially viable, and acceptable to the Puna communities.
2. Identify possible sites that could be used for geothermal direct use businesses.
3. Identify possible geothermal resources in Kapoho outside of PGV's lease that could be utilized for geothermal direct use.
4. Estimate capital and operational costs.
5. Estimate viable unit costs for heat.
6. Identify positive and negative impacts on the community of a geothermal direct use enterprise park.
7. Research the legal basis for accessing the County of Hawaii's Geothermal Asset and Geothermal Royalty funds.
8. Develop a plan to promote the economic benefits of geothermal direct use in the County of Hawaii.

Design services for infrastructure and geothermal enterprise park development, environmental studies, permitting, and exploratory drilling efforts were excluded from the feasibility study objectives.

1.3 FEASIBILITY STUDY APPROACH AND FLOW CHART

There is a tremendous amount of information available regarding direct uses of geothermal heat. A systematic approach was employed to focus feasibility study research and evaluation efforts on project and site specific relevant information. The approach emphasized an integrated effort that considered the objectives in a comprehensive manner. See Chart 1-1 for a flow chart description of research efforts.

The first step was to develop a list of geothermal direct use enterprises that are potentially viable and acceptable to the Puna communities. A geothermal direct use enterprise was deemed viable if it supports existing industries, is sustainable, and has the potential to generate significant income.

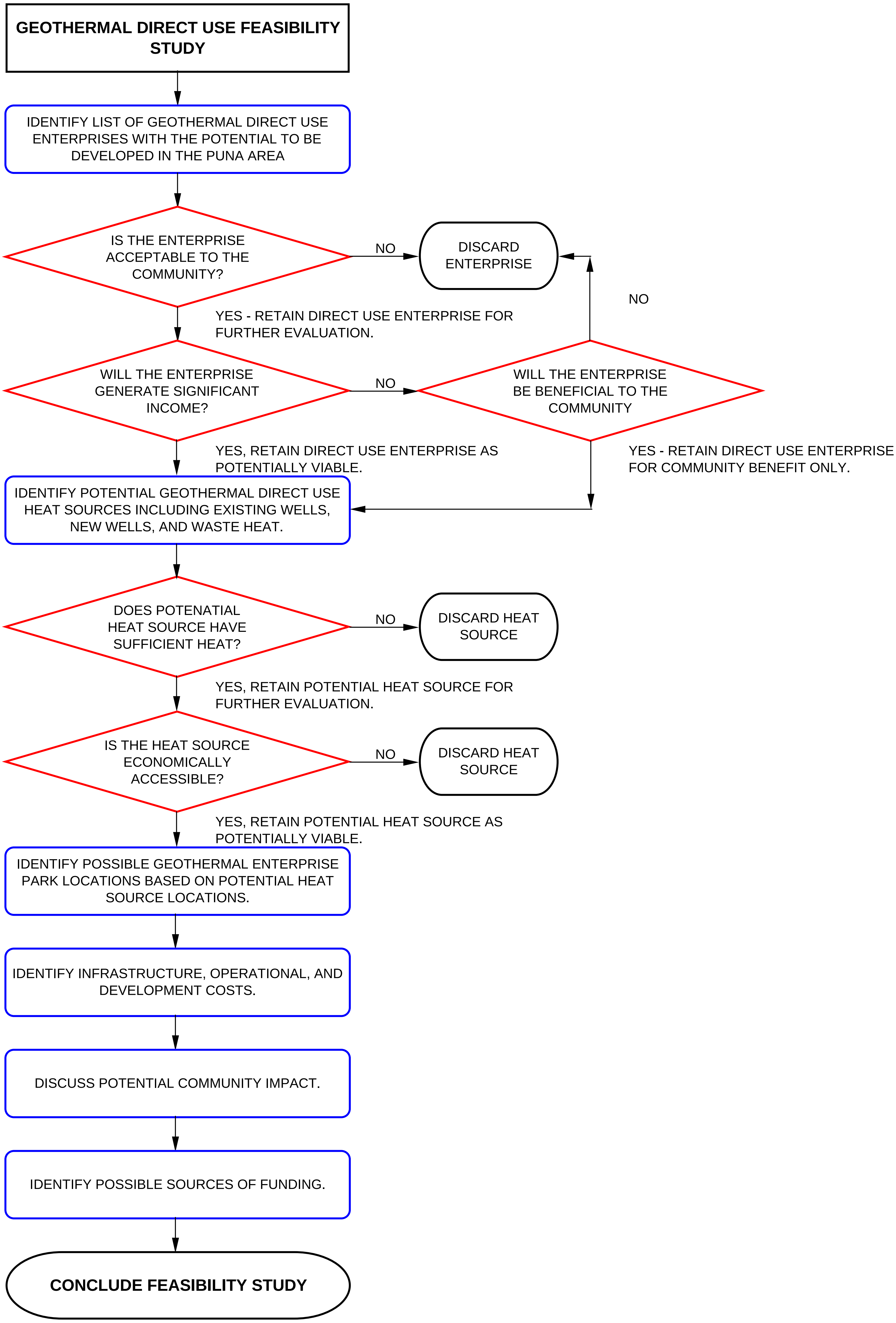
The second step was to identify potential geothermal heat sources. A heat source was deemed potentially viable if it has the ability to produce significant quantities of heat and is economically accessible.

The third step was to identify possible site(s) for a geothermal enterprise park based on the location(s) of potential geothermal heat source(s), access to utilities, and land zoning.

The fourth step was to give an opinion of probable construction cost required to construct the necessary infrastructure, cost required to develop and construct an enterprise park, and cost to operate and maintain an enterprise park. Possible revenue was also estimated based on existing utility rates and estimated energy usage.

The fifth step was to discuss the potential impact on the community of a geothermal enterprise park and to develop an economic promotional plan.

CHART 1-1: GEOTHERMAL DIRECT USE FEASIBILITY STUDY FLOW CHART



The sixth step was to identify possible sources of funding for a geothermal direct use enterprise park and individual geothermal direct use businesses based on potentially viable geothermal direct use enterprises, possible site(s) of a geothermal direct use enterprise park, and proposed geothermal legislation.

The final step was to assemble all of the information and determine if direct uses of geothermal heat is feasible based on community support, technical feasibility, and ability to be economically self sufficient.

CHAPTER 2 – GEOTHERMAL DIRECT USE ENTERPRISES

2.1 INTRODUCTION

This chapter will discuss the methodology used to identify geothermal direct use enterprises that are potentially viable and acceptable to the Puna community. A three-step approach was utilized. The first step was to identify geothermal direct use enterprises that may have the potential to be developed in the Kapoho / Pohoiki area. The second step was to solicit feedback regarding geothermal direct use enterprises that may have the potential to be developed in the Kapoho / Pohoiki area, and to determine which ones are acceptable to the Puna community. The third step was to briefly evaluate and identify basic requirements for each geothermal direct use enterprise which is acceptable to the Puna community, and determine which geothermal direct use enterprises could be viable in terms of sustainability, income producing potential, and support of existing Hawaii industries.

Four geothermal direct use enterprises were identified as being acceptable to the Kapoho / Pohoiki community, were determined to be potentially viable, and were retained for possible commercial development consideration. The four selected applications were greenhouses, pasteurization of potting media, biodiesel production, and lumber kilns. Nine geothermal direct use enterprises were identified as having high Kapoho / Pohoiki community appeal, but offer limited income producing potential and / or are small consumers of heat. These nine geothermal direct use enterprises including fruit drying, seed drying, food processing, papaya disinfection, community commercial kitchen, drying fish, laundromat, university research center, and hot water treatment for coqui eradication were retained for possible small scale development consideration. The remaining geothermal direct use enterprises were determined to be non-viable or unlikely to be viable.

2.2 IDENTIFYING GEOTHERMAL DIRECT USE ENTERPRISES

A list of geothermal direct use enterprises that may have the potential to be developed in the Kapoho / Pohoiki area were identified through the use of numerous references available from DBEDT, DOE, County of Hawaii, and Oregon Institute of Technology (OIT). Geothermal direct use enterprises that are intended for cold climate applications, such as district heating and snow melting, or which support industries no longer extant on the Island of Hawaii, such as ethanol production from sugarcane, were omitted from the list.

The following enterprises comprise the list of geothermal direct use enterprises that were initially deemed to have the potential to be developed in the Kapoho / Pohoiki area:

- Aquaculture (Fish Farms)
- Fruit/Vegetable Drying (Bananas, Mangos, Noni, Papayas, Pineapples, etc.)
- Greenhouses (Greenhouses and Bottom Soil Heating)
- Soil Treatment (Sterilization of Potting Media)
- Seed Drying
- Food Processing (Tea and Vegetables)
- Papaya Disinfection
- Community Commercial Kitchen
- Drying Concrete Blocks
- Drying Fish
- Ethanol Distillation (Production)
- Biodiesel Production
- Ice Plant, Cold Storage, and or Refrigeration
- Laundromat
- Lumber Drying (Kilns)
- Rumber® Production (Planks Made From Used Tires)
- Soap Making

- Bathing Facilities (Public or Private) / Spas & Onsen
- Swimming Pool.

2.3 ACCEPTABLE DIRECT USE ENTERPRISES

Many communities are sensitive to developments in their backyard and it is believed that community involvement could go a long way towards the successful planning / development of a geothermal direct use enterprise park in the Kapoho / Pohoiki area. It was determined that geothermal direct use enterprises with the potential to be viable should first have the support of the community before being evaluated and considered for development. The County began efforts to inform and solicit public opinion regarding geothermal direct use in 2005 with the assembly of the Hawaii Island Geothermal Direct Use Working Group (Working Group). The Working Group was charged with numerous tasks including providing geothermal direct use information to the community and soliciting public opinion. See Section 2.3.1 for a summary of the 2005 Working Group efforts.

This feasibility study expanded on the successful efforts of the 2005 Working Group and took a grass roots approach towards soliciting additional comments and opinions from the community. Questionnaires were distributed via the Working Group, County of Hawaii Puna District Community Development Plan meetings, 2006 Earth Day at the University of Hawaii at Hilo campus, and the University of Hawaii at Hilo College of Agriculture, Forestry and Natural Resource Management (UHH CAFNRM). Questionnaires were also distributed to several local organizations including the Office of Hawaiian Affairs (OHA) and the Kapoho Land Company. See Section 2.3.2 and 2.3.3 for a summary of the responses.

2.3.1 2005 Working Group Efforts

The Working Group hosted several public meetings in 2005 to educate interested Puna community members, County political leaders, and the agricultural community about geothermal direct use enterprises. The Working Group was established in 2005 to discuss direct uses of geothermal heat, provide information on direct uses of geothermal heat to the community, and solicit community opinion related to direct uses of geothermal heat.

The first public meeting hosted by the Working Group was held on April 21, 2005 at the Leilani Estates Community Center. The meeting attracted four members of the public including an individual associated with Malama O Puna, an environmental non-profit group. The general sentiment expressed was that geothermal direct use is acceptable and that it has tremendous potential. The group also expressed the following ideas and desirable characteristics of geothermal direct use enterprises:

- Minimal negative impacts on the residential population
- Effective abatement of any noise or chemicals
- Driven by members of the community rather than larger business corporations
- Affordable for small businesses
- No exploitation of free heat for those who have funding capacity
- Includes educationally driven enterprises
- Noni, papaya and pineapple and other agricultural crops could provide opportunities to create added-value ventures
- Consider a mixed-use facility / kitchen
- Making soap from papaya wastes
- Drying concrete blocks and making Rumber® (planks made from used tires)
- Making ice for the fishermen operating out of Pohoiki small boat harbor.

The second public meeting hosted by the Working Group was held on August 16, 2005 for the Hawaii County Council's Committee of Human Services and Economic Development. Dr. John Lund, Director of OIT's Geo-Heat Center made a presentation on behalf of the Working Group. The presentation was well received and televised on public access television.

The third public meeting hosted by the Working Group was held on August 16, 2005 at the University of Hawaii at Hilo Cooperative Extension Service conference room. Dr. John Lund presided over the meeting, which was geared towards businesses and agricultural commodity groups. Sixteen attendees representing nine commodity groups expressed high interest. The attendees' interests included potted orchids, cut flowers, soil treatment, aquaculture, lumber processing, bamboo drying, tea and vegetable processing, food processing, and spas. The group was generally concerned with costs, heating capability, geothermal water quality, sources of funding, and when geothermal heat would be available for their use.

The fourth public meeting hosted by the Working Group was held on August 16, 2005 at the Pahoa Community Center. The meeting attracted five members of the public. Working Group members and Dr. John Lund made presentations at the meeting. Most of the topics of discussion and concern regarded short and long term impacts, permits, regulations, costs and project status. The group also expressed the following:

- Use the 4-acre Natural Energy Laboratory of Hawaii Authority (NELHA) site near Pahoa to make and store ice for local fishermen
- Ensure that the facility supports multiple uses
- Provide boat parking and storage
- Explore greenhouse applications (for the Malama Ki Ag. Station)
- Consider direct use applications such as making and storing ice, drying timber, drying produce, residential use, spas & resorts, sterilization, and bottom heating.

The fifth public meeting hosted by the Working Group was held on August 17, 2005 at the Hilo Bay Rotary Club. Dr. John Lund presided over the meeting geared towards the business community. The meeting was well attended with 50~60 participants. No particular concerns were raised at the meeting.

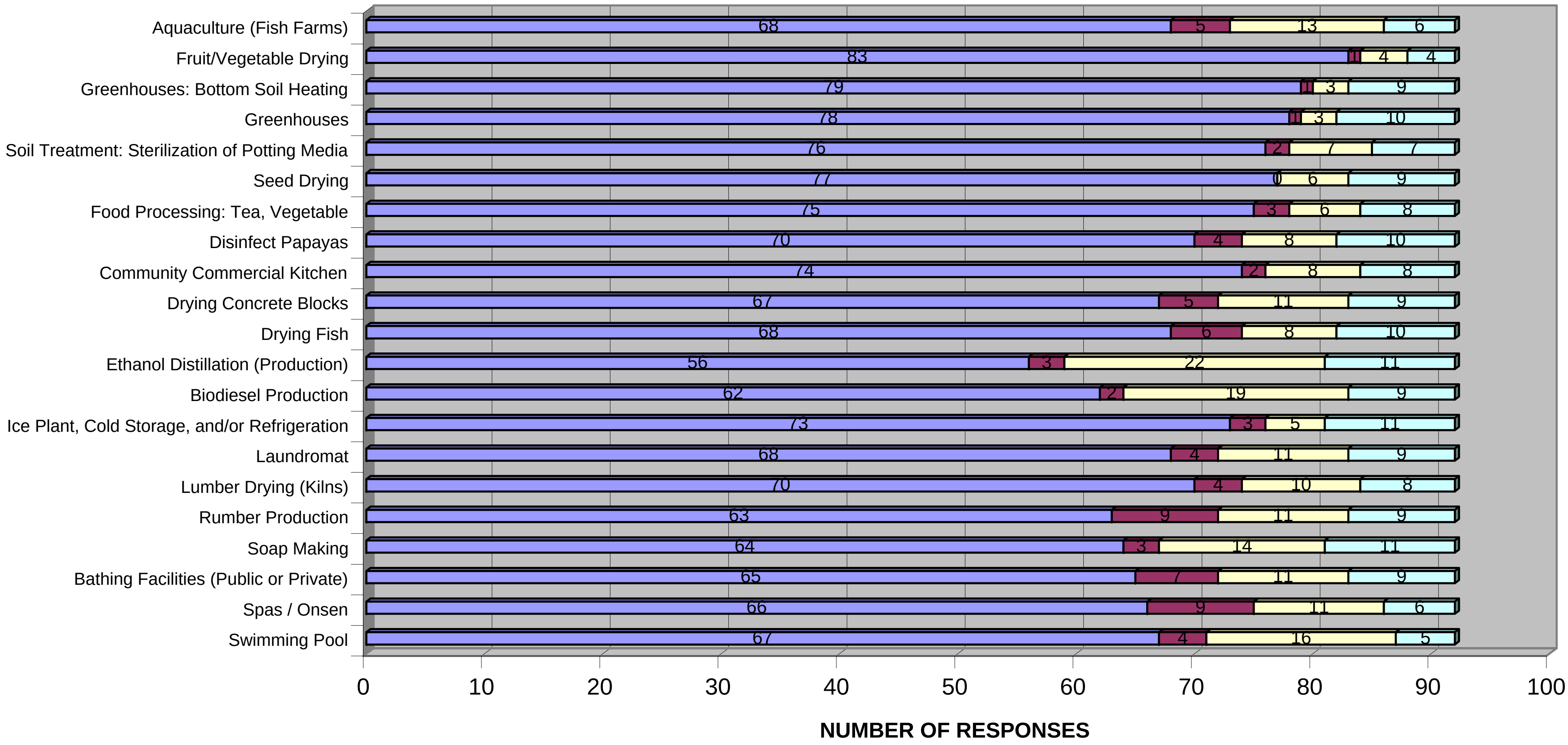
2.3.2 Feasibility Study – Questionnaire Responses

Questionnaires were distributed via the Working Group, County of Hawaii Puna Community Development Plan meetings, 2006 Earth Day, and UHH CAFNRM to gauge public sentiment towards geothermal direct use. The questionnaire was distributed with a fact sheet compiled by the County, and figures prepared by the Working Group. The questionnaire presented 21 geothermal direct use enterprises that may have the potential to be developed in the Kapoho / Pohoiki area. Respondents were asked their opinion of each direct use enterprise (i.e., approve, disapprove, neutral), whether they were interested in starting a business utilizing geothermal heat, and whether they had any comments. See Appendix A for a sample questionnaire.

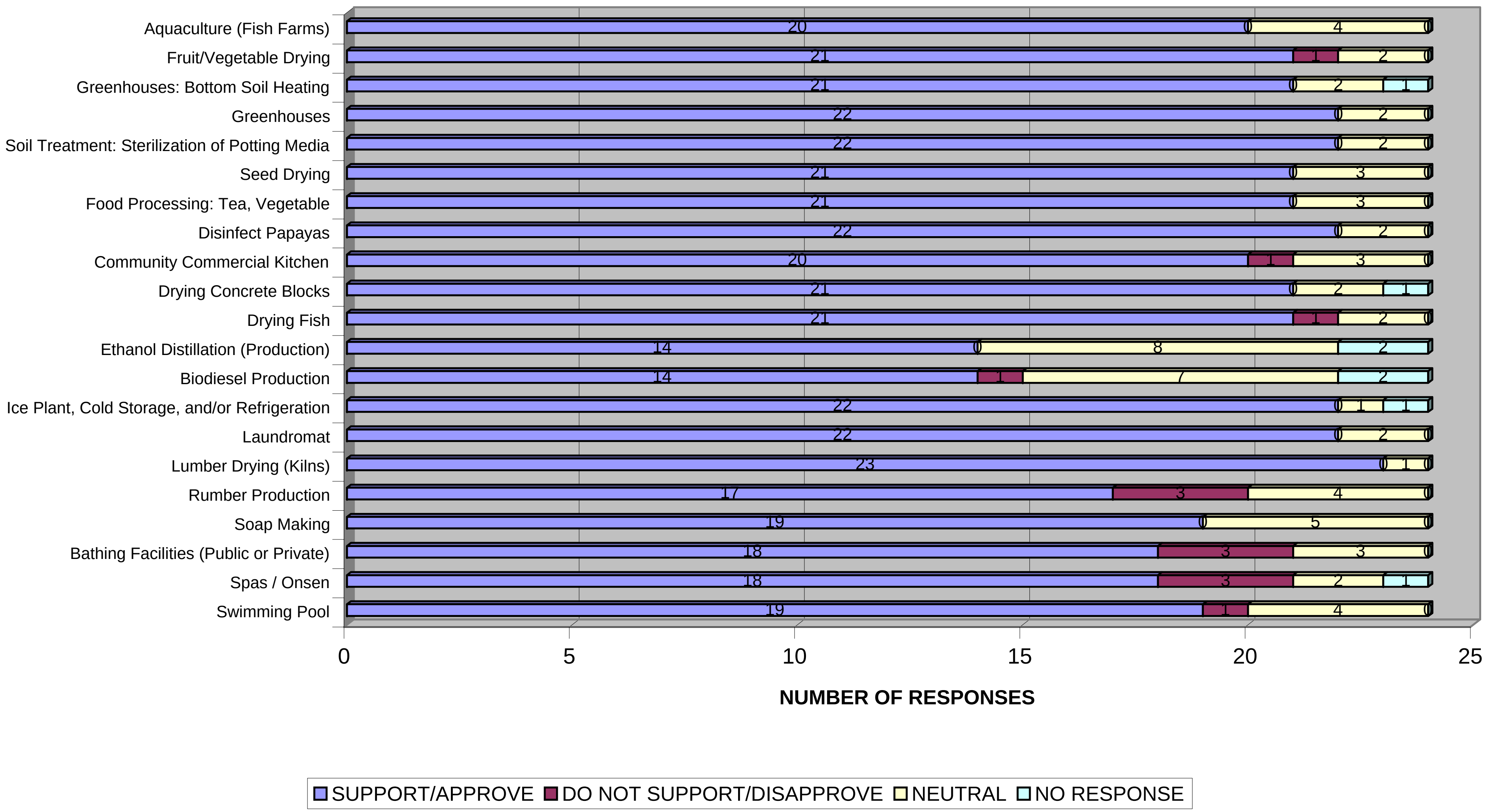
The results were compiled and separated into three groups where one group included all of the respondents, one group included only the Pahoa community respondents, and one group included only the non-Pahoa community respondents. Respondents who indicated a Pahoa area mailing address were assumed to be Pahoa residents. Respondents who indicated a non-Pahoa area mailing address or who declined to indicate a mailing address were assumed to be non-Pahoa residents. Ninety-two questionnaire responses were received of which 24, or 26%, were from Pahoa residents. See Charts 2-1A, 2-1B, and 2-1C for responses to the direct use enterprises. See Chart 2-2 for overall general responses to direct use of geothermal energy. See Chart 2-3 for respondents interested in starting a geothermal direct use enterprise business.

General sentiment among the respondents was one of support and approval for geothermal direct use enterprises. Approval ratings among all respondents

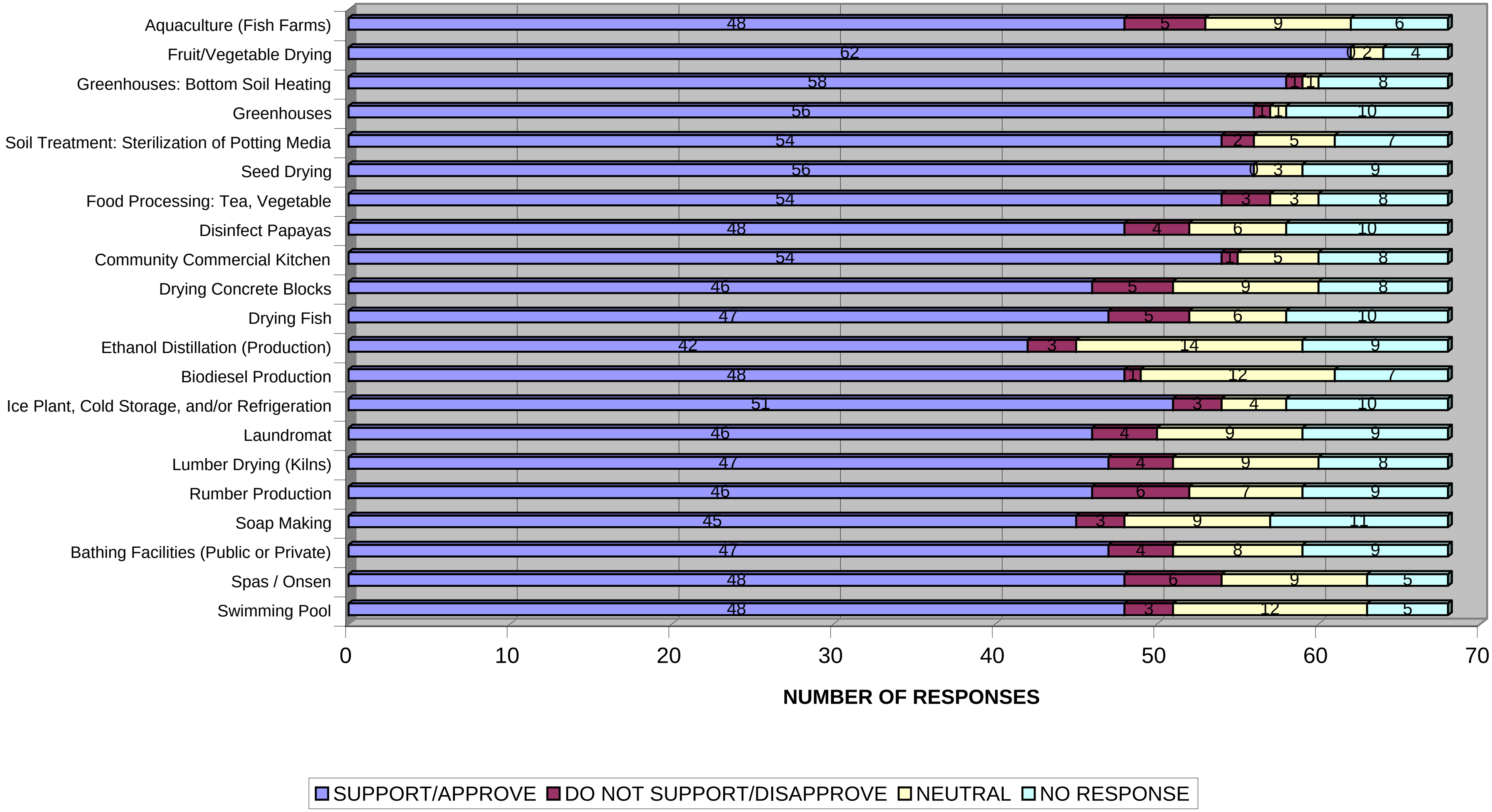
GEOTHERMAL DIRECT USE ENTERPRISES
CHART 2-1A: DIRECT USE ENTERPRISES (GRAND TOTAL)



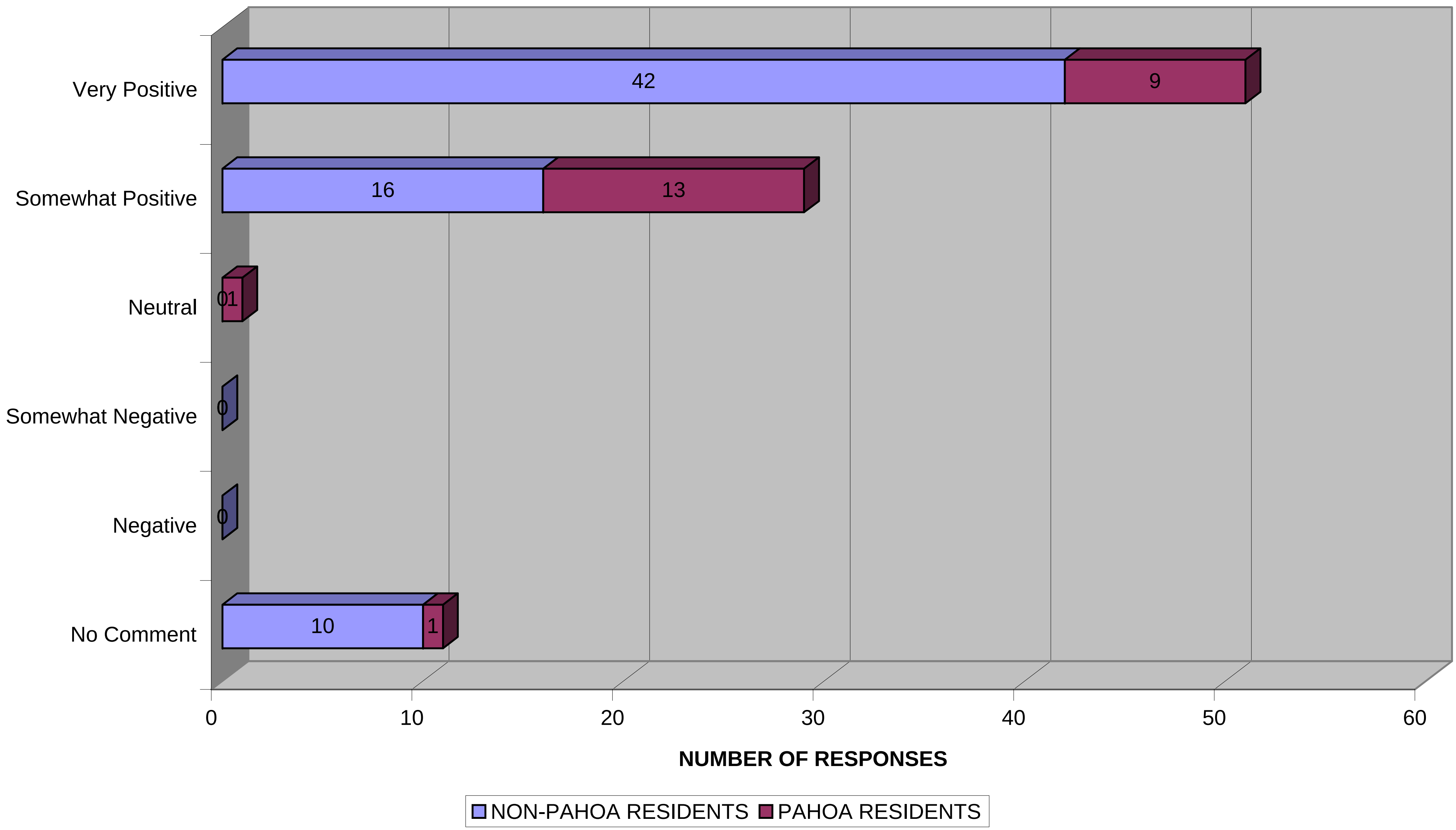
GEOTHERMAL DIRECT USE ENTERPRISES
CHART 2-1B: DIRECT USE ENTERPRISES (PAHOA RESIDENTS TOTAL)



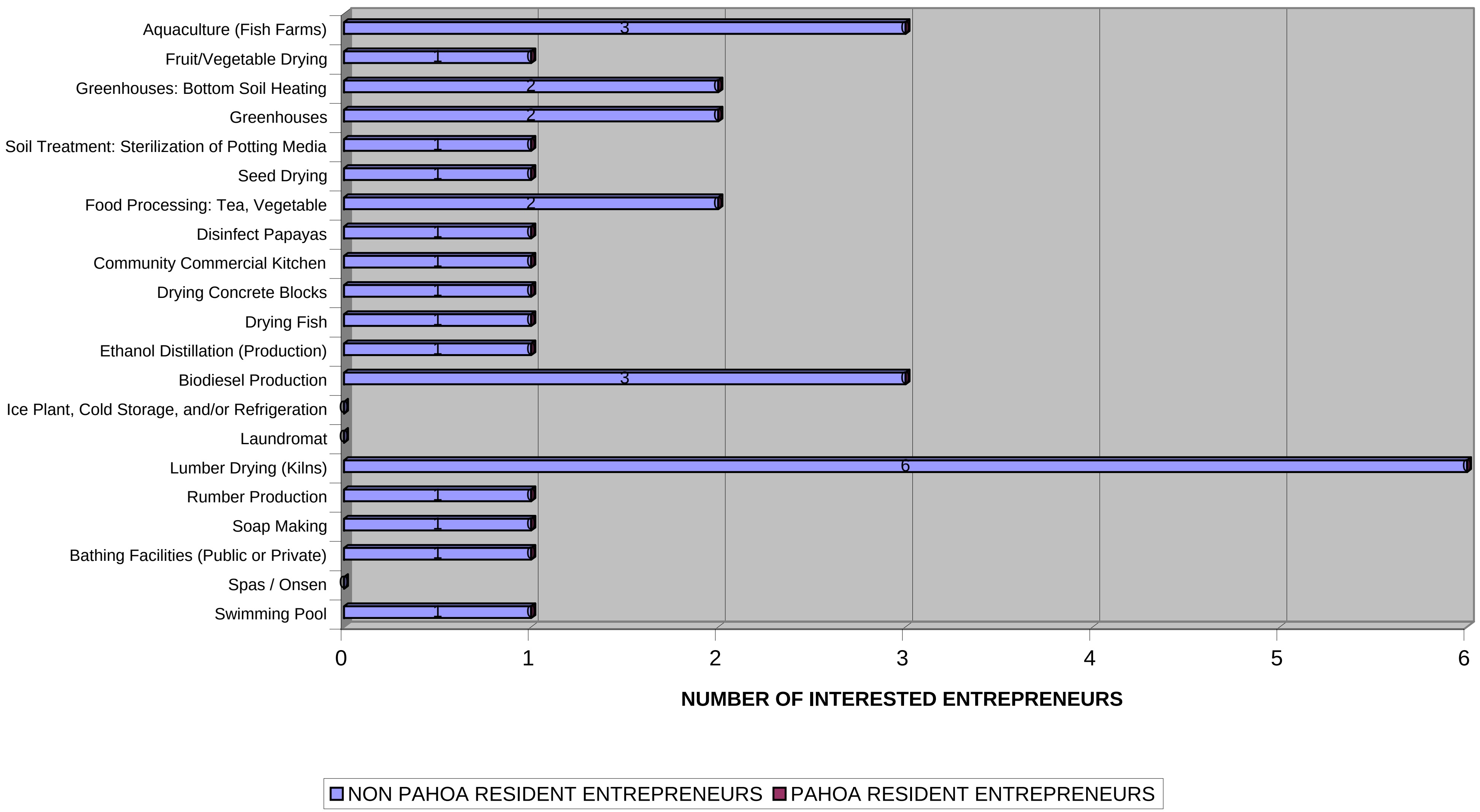
GEOTHERMAL DIRECT USE ENTERPRISES
CHART 2-1C: DIRECT USE ENTERPRISES (NON PAHOA RESIDENTS TOTAL)



GEOTHERMAL DIRECT USE ENTERPRISES
CHART 2-2: GEOTHERMAL DIRECT USE SENTIMENT IN GENERAL



GEOTHERMAL DIRECT USE ENTERPRISES
CHART 2-3: INTERESTED DIRECT USE ENTERPRISE ENTREPRENEURS



ranged from a low of approximately 61% for Ethanol Distillation up to a high of approximately 90% for Fruit and Vegetable Drying. Disapproval ratings among all respondents ranged from a low of 0% for Seed Drying up to a high of approximately 10% for Rumber® Production and Spas / Onsen.

Approval ratings among Pahoa resident respondents ranged from a low of approximately 60% for Ethanol Distillation and Biodiesel Production up to a high of approximately 95% for Lumber Drying (Kilns). Disapproval ratings among Pahoa resident respondents ranged from a low of 0% for 13 of the 21 geothermal direct use enterprises to a high of approximately 12.5% for Rumber® Production, Bathing Facilities, and Spas / Onsen.

There were a significant percentage of both Pahoa and non-Pahoa resident respondents that were either neutral or provided no response towards many of the 21 geothermal direct use enterprises. Possible reasons for respondents deferring to comment on some of the geothermal direct use enterprises could be due to varying self interests (i.e., business related, hobbies, and quality of life), lack of interest, or lack of sufficient information to express an informed opinion.

Pahoa resident respondents seem to strongly endorse agricultural and agriculture-supporting geothermal direct use enterprises. They also seem to somewhat support industrial or vanity / personal hygiene geothermal direct use enterprises, albeit not as strongly and with some disapproval. These results appear to verify previous findings of the 2005 Working Group outreach efforts. See Section 2.3.1 for a discussion of the 2005 Working Group findings.

Non-Pahoa resident respondents seem to have a similar opinion of geothermal direct use enterprises as the Pahoa resident respondents, except non-Pahoa resident respondents seem to be less enthusiastic about agriculture-supporting geothermal direct use enterprises such as ice production (i.e., ice plant), cold storage, disinfecting papayas, drying fish, and drying lumber (i.e., lumber kilns).

Interestingly, it appears that Pahoa residents seem to support geothermal direct use enterprises more than non-Pahoa residents as shown on Charts 2-1B and 2-1C. However, Pahoa residents also seem to be more cautious about their support as is evident in the lower "Very Positive" sentiment and higher "Somewhat Positive" sentiment versus non-Pahoa residents' sentiment shown on Chart 2-2. It is believed that this is a reflection of the Kapoho / Pohoiki community attitude towards energy, jobs, sustainability, and geothermal energy. The community seems to hold energy efficiency, energy independence from oil, creation of appropriate jobs, and community and environmental sustainability in high regard. At the same time, they seem to remember the history of geothermal energy development in the area and mishaps that have occurred throughout its maturation. The following are all of the general comments received from survey respondents. Specific comments regarding each geothermal direct use enterprise can be found in the various subsections of Section 2.4.

General Comments from Questionnaire Respondents:

- It's all good if how they do it now is with petroleum.
- [Interested in] jobs in Pahoa.
- I enthusiastically encourage non-electrical uses of geothermal heat.
- In general, as long as there are no negative environmental/local impacts.
- Interested in anything that will release us from our dependence on oil.
- [Interested in] electric cooperative.

Feelings and Comments from Questionnaire Respondents:

- [Very Positive] Why waste the heat?
- [Very Positive] It's only a matter of time until the positives outweigh the negative.
- [Very Positive] We should make use of it.
- [Very Positive] I think it's a good thing that will help the County of Hawaii. And it might help. I want to see changes new things.
- [Very Positive] Natural resource that should be harvested for "good" purposes.
- [Very Positive] This will cut down energy cost, create business opportunities in Puna and employment associated with heated businesses.
- [Very Positive] Seems like there is a lot more we could be doing with it.
- [Very Positive] Electric generation not very effective / best use of heat.
- [Very Positive] Efficient use of low level heat.
- [Very Positive] Glad to see the level the group is operating at. I support your efforts.
- [Very Positive] Oil is our downfall. Get us off oil.
- [Very Positive] It seems like a great way to conserve electricity using clean methods and it's so available here too.
- [Very Positive] To get away from fossil fuel.
- [Very Positive] Alternative energy.
- [Very Positive] We must tap Pele power if we are to Malama Aina.
- [Very Positive] We need very much to utilize clean alternative energy sources to make this change from oil and become more self sufficient.
- [Very Positive] Any alternative energy source at this point would be extremely important for the well being of this island and the world.
- [Very Positive] It is a natural energy source that should be utilized.
- [Very Positive] Using a natural source of energy other than oil is of interest to me.

- [Very Positive] I strongly support alternative energy sources.
- [Very Positive] The energy from the earth is a smart, clean and available way for the people of Hawaii to meet our energy needs. It is surprising that more has not been done to harness this energy.
- [Very Positive] Get away from oil and its pollution.
- [Very Positive] A way to attract new industries to locate on the Big Island.
- [Very Positive] Utilize the resource effectively.
- [Very Positive] So many other things that need energy.
- [Very Positive] Anywhere one might responsibly utilize resources already in place, I endorse.
- [Very Positive] Don't want to be dependent on oil to make our electricity.
- [Very Positive] Good to develop choices for our energy needs. Hopefully having energy other than electric will lower our energy cost. Also, a way to conserve our resources.
- [Very Positive] Seems like this could open up a lot of business opportunities and provide jobs for the people in Puna.
- [Very Positive] It is found on the Big Island, will be less dependent on oil, may bring prices down.
- [Very Positive] Create jobs and open up new business opportunities.
- [Very Positive] I think Puna has this natural resource and we should use it to better our community and State. Low energy prices.
- [Very Positive] transfer away from oil! Sustainable and renewable energy.
- [Very Positive] We need to catch up with other places that use geothermal.
- [Very Positive] We support any activity that will assist the advancement of mankind without the use of fossil fuel.
- [Very Positive] No waste.

- [Very Positive] Logical.
- [Very Positive] We desperately need to reduce our dependence on oil.
- [Very Positive] Great for the community.
- [Very Positive] Great.
- [Very Positive] I feel that geothermal direct use is necessary to move toward a path of environment responsibility.
- [Very Positive] Sustainable and ecological.
- [Very Positive] Because of the natural aspects of using heat/energy that's already been produced.
- [Very Positive] Anything to recycle.
- [Very Positive] Go for it.
- [Very Positive] May as well use the excess heat for good.
- [Very Positive] Iceland is a self supporting country similar to Hawaii because of thermal energy.
- [Very Positive] Because it promotes a focus on healthier friendlier alternatives to typical consumption.
- [Very Positive] As a collective group this island produces tons of waste bamboo that could be steam split and used to make infinite useful products.
- [Very Positive] This could help the community by having local businesses in Puna instead of having people drive to Hilo. Personally I'm interested in starting a pulp mill using geothermal for steam and electricity.
- [Very Positive] Make good use of excess steam, (heat). Sawmills usually produce electricity from their by products and then use the excess steam for their dry kilns. Nothing new, but the geothermal needs a consistent and high temperature supply.
- [Somewhat Positive] Negative effects of geothermal are unclear.
- [Somewhat Positive] Beneficial use of "waste" resource.

- [Somewhat Positive] Negative impacts are also present in addition to positive.
- [Somewhat Positive] Should use whatever energy value that can be used.
- [Somewhat Positive] Worried about negative impact of increase in CO in air and affecting nearby residents.
- [Somewhat Positive] I guess I see it as benefits utilizing the energy to help the community and people.
- [Somewhat Positive] It seems like a great way to use our resources, but I'm not clear about whether or not there are harmful byproducts.
- [Somewhat Positive] Natural energy – cost effective.
- [Somewhat Positive] I don't know much on how it works.
- [Somewhat Positive] Will it happen?
- [Somewhat Positive] Excess electricity or dedicated to pool.
- [Somewhat Positive] Concerned about toxic emissions thoroughly controlled.
- [Somewhat Positive] Ethanol is much needed to reduce the dependency on oil use. Plants themselves will improve life in Hawaii.
- [No Response] Not enough information.
- [No Response] Natural energy should be used so we can get away from oil and coal use.

<u>Questions from Questionnaire Respondents:</u>

- Need more information on disposal of H2O. What's in it? Where is it going?
- Do you envision directly using geothermal steam? Meaning are you looking at tapping into the resource or only going down enough to get heat? I fully support uses without using the resource directly.

Additional Direct Use Enterprise Suggestions from Questionnaire Respondents:

- Homeopathic production.
- Anything to reduce use of fossil fuel and recycle.
- Cleaning up some areas without chemicals using heated water.
- We are interested in the possibility of steam splitting the bamboo we provide for use in manufacturing various products. Our questions concern the temperature and pressures available. Please send us more information if possible.
- Steam for pulping plant (non-wood or recovered paper).

The comments suggest that the community is interested in geothermal direct use development but have several misconceptions including the release of carbon monoxide/dioxide, which are emissions generally associated with fossil-fuel power plants but not geothermal energy. Many of the concerns are minor in nature and can either be resolved with further educational outreach, or the implementation of appropriate design features.

Based on the positive responses from both Pahoa and non-Pahoa residents, it was decided that all 21 of the geothermal direct use enterprises with the potential to be developed in the Kapoho / Pohoiki area should be evaluated further. It was felt that the overwhelming support (61%~90% overall approval rating) among respondents warranted further discussion.

There are a number of individuals who expressed interest in starting a business based on geothermal direct use for 18 of the 21 geothermal direct use enterprises. See Chart 2-3 for the number of potential geothermal direct use entrepreneurs based on questionnaire responses and correspondence received from interested individuals.

2.3.3 Feasibility Study – Letter Responses

Letter responses were received from two individuals and one major Pahoa / Pohoiki area landowner. See Appendix B for copies of the letters. Mr. Winkler, a local businessman and consultant expressed interest in assisting to develop and market geothermal heat source lumber drying. Mr. Lockwood, a local volcanologist expressed enthusiastic support for geothermal energy. The Kapoho Management Company, Inc., and the Kapoho Land and Development Company, Ltd. also expressed support of geothermal resources.

2.4 GEOTHERMAL DIRECT USE ENTERPRISE REQUIREMENTS

Each geothermal direct use enterprise was evaluated to ascertain whether it was potentially viable in the Kapoho / Pohoiki area. The evaluation was very limited in nature and only identified basic geothermal direct use enterprise selection criteria. A comprehensive business and engineering plan will be required to make a definitive determination whether each geothermal direct use enterprise is viable. Among the basic criteria used to evaluate potentially viable geothermal direct use enterprises include the following:

- What temperature heat does the geothermal direct use enterprise require? Only direct use enterprises that can be supported by available geothermal resources were considered.
- Has the geothermal direct use enterprise been proven viable elsewhere in the world? Direct use enterprises that have been successfully developed are clearly viable under proper conditions. Direct use enterprises that have failed were evaluated with skepticism. Unproven enterprises were evaluated with caution and would likely require research and development to prove their viability.
- Is the geothermal direct use enterprise supported by the community?
- Will the geothermal direct use enterprise help the community?
- Does the geothermal direct use enterprise make sense?

- Are there any significant barriers to development?

See Table 2-1 for a summary of the geothermal direct use enterprises' evaluation.

2.4.1 Aquaculture

Aquaculture is a proven geothermal direct use enterprise that has experienced tremendous success in cold climate areas. The most common species raised in geothermally heated waters include catfish, tilapia, bass, trout, sturgeon, giant fresh water prawns, and tropical fish. Additionally, species have been found to grow at accelerated rates under controlled ideal temperature conditions (Lienau 2005).

The aquaculture market has been growing in Hawaii with total sales of approximately $28.1 million in 2004. Approximately 75% of the Hawaii State aquaculture product, worth $21.2 million, was produced on the Island of Hawaii (Hawaii, DBEDT August 2006).

Of all of the aquaculture species raised in Hawaii, tilapia and tropical ornamental fish may be the most likely to benefit from geothermally heated waters. Shallow geothermal well water in the Kapoho / Pohoiki area is slightly brackish and may limit the number of species that could thrive in it. Deep geothermal well water in the Kapoho / Pohoiki area is probably unsuitable for direct aquaculture use due to its chemical content. There is one aquaculture company in the Kapoho / Pohoiki area that utilizes brackish water from a shallow geothermal well to raise ornamental fish. Although the company reportedly does not take advantage of heated water to raise the fish, it clearly demonstrates that certain types of ornamental fish can thrive in brackish water from the Kapoho / Pohoiki shallow geothermal wells.

GEOTHERMAL DIRECT USE ENTERPRISES
TABLE 2-1: DIRECT USE ENTERPRISE EVALUATION SUMMARY
(Sheet 1 of 2)

Geothermal Direct Use Enterprise	Required Temperature (deg F)	Proven Enterprise	Supported By Community (Yes/No/Neutral)	Help Community	Make Sense	Significant Barriers
Aquaculture	100~120 water (Actual temperature can vary)	Yes	(68 / 5 / 13)	Somewhat	Unlikely	Studies are needed to determine which fish species can succesfully be raised in Kapoho / Pohoiki geothermal waters. Fish raised in Hawaii would likely need to be exported in order to be profitable. The added cost and complexity of using geothermally heated water would need to be offset by the value added by accelerated fish growth. Accelerated growth rates can reportedly adversely affect fish flesh quality. Accelerated growth rates will need to be balanced against fish quality. Market development would need to be conducted to promote locally raised tilapia and to remove the negative stigma surrounding tilapia. Expected return on investment is expected to be low.
Fruit Drying	130~185 water (120~175 air)	Yes	(83 / 1 / 4)	Somewhat	Somewhat	Fruit drying is labor intensive, Hawaii labor is expensive, and it would be difficult to compete with the global market. Hawaii would need to market its products towards niche demands, as local coffee is marketed, rather than trying to compete with global commodities. Available quantities and different types of fruits that can be dried are limited. The Kapoho / Pohoiki area would need to produce enough fruit to support drying. Fruit drying would likely be a supporting industry because many of the crops in Hawaii are relatively expensive and seem to fetch the highest prices when sold fresh. Previous studies have concluded that fruit drying would be marginally profitable at best.
Vegetable Drying	150~210 water (140~200 air)	Yes	(83 / 1 / 4)	No	No	Vegetable drying is labor intensive, Hawaii labor is expensive, and it would be difficult to compete with the global market. Hawaii would need to market its products towards niche demands, as local coffee is marketed, rather than trying to compete with global commodities. Available quantities and different types of vegetables that can be dried are limited. The Kapoho / Pohoiki area would need to produce enough vegetables to support drying. Vegetable drying would likely be a supporting industry because many of the crops in Hawaii are relatively expensive and seem to fetch the highest prices when sold fresh. Most types of vegetables grown in Hawaii are not typically dried.
Greenhouses: Bottom Soil Heating	100 water	Yes	(79 / 1 / 3)	Yes	Yes	Hawaii has a temperate environment. Will increased crop production warrant moving of established businesses? Is sufficient acreage available?
Greenhouses	100 water	Yes	(78 / 1 / 3)	Yes	Yes	Hawaii has a temperate environment. Will increased crop production warrant moving of established businesses? Is sufficient acreage available?
Soil Treatment: Sterilization of Potting Media	150 water~260 steam (140~250 air)	No	(76 / 2 / 7)	Yes	Yes	Imported potted media costs may not justify pasteurizing / sterilizing and recycling potted media at this time. Recycling of potted media may have an adverse effect on the growth and quality of potted plants.
Seed Drying	Unknown	No	(77 / 0 / 6)	Unknown	Unknown	Similar to fruit and vegetable drying barriers.
Food Processing (Tea and Vegetable)	Unknown	No	(75 / 3 / 6)	Unknown	Unknown	Similar to fruit and vegetable drying barriers.
Papaya Disinfection	Unknown	No	(70 / 4 / 8)	Somewhat	Unlikely	It would be cost prohibitive to relocate existing papaya production facilities to Kapoho / Pohoiki. The existing Island of Hawaii processing plants are not operating at capacity.
Community Commercial Kitchen	120~160 water	Somewhat	(74 / 2 / 8)	Somewhat	Somewhat	A community kitchen is not a viable geothermal direct use enterprise in itself. It is only viable if there are other geothermal direct use enterprises that require a commercial kitchen. A source of funding to design and construct a community kitchen needs to be identified. A community kitchen requires strong community support to be successful. It is not clear that there would be sufficient demand for a community kitchen by the Kapoho / Pohoiki community. Other Island of Hawaii community kitchens have met with very limited success. There are other commercial kitchens that the Kapoho / Pohoiki community can use including schools, chrches, and some private establishments.
Drying Concrete Blocks	130~180 water	Yes	(67 / 5 / 11)	Unknown	No	There are competing concrete companies located closer to construction areas on the Island of Hawaii. This is an industry type application that portions of the community may protest against.

GEOTHERMAL DIRECT USE ENTERPRISES
TABLE 2-1: DIRECT USE ENTERPRISE EVALUATION SUMMARY
(Sheet 2 of 2)

Geothermal Direct Use Enterprise	Required Temperature (deg F)	Proven Enterprise	Supported By Community (Yes/No/Neutral)	Help Community	Make Sense	Significant Barriers
Drying Fish	85~130 water (75~120 air)	Yes	(68 / 6 / 8)	Somewhat	Somewhat	The price of geothermally dried fish would need to be higher than the price of fresh fish to be viable. It is unknown whether the quantity of fish landed at Pohoiki Bay is sufficient to support a geothermal fish drying facility
Ethanol Distillation	steam	Somewhat	(56 / 3 / 22)	Somewhat	Yes*	There are competing ethanol plants under development on each island. This is a industrial type application that many of the residents may not support in their backyard. There are no conventional feedstocks (sugar cane or corn) available on the Island of Hawaii.
Biodiesel Production	210 water~steam	No	(62 / 2 / 19)	Yes	Yes*	Feedstocks need to be imported.
Ice Plant, Cold Storage, Refrigeration	185~350 water / steam	Yes	(73 / 3 / 5)	Unknown	No	There is insufficient heat available to effectively make ice. The demand for ice and cooling may not justify installing expensive mechanical equipment.
Laundromat	120~160 water	No	(68 / 4 / 11)	Likely	Unlikely	The Kapoho / Pohoiki area may not be growing fast enough to warrant another laundromat. The enterprise park will likely be located outside of the town limits.
Lumber Kilns	90 water~steam (80~240 air)	Somewhat	(70 / 4 / 10)	Likely	Yes	It is uncertain that the net savings of replacing utility heating with geothermal heat and added transporation costs would warrant relocating established businesses. There are competing methods of drying lumber.
Rumber	200~210 water (190~200 heat)	No	(63 / 9 / 11)	Somewhat	Unlikely	It is unclear whether there is a sufficient amount of raw materials on the Island of Hawaii. High transportation costs. The market for Rumber products is unproven in Hawaii.
Soap Making	Unknown	No	(63 / 4 / 14)	Unlikely	No	Will not create many jobs or significant income? It will be difficult to utilize the geothermal heat to produce soap. Transportation costs will likely offset any energy savings.
Bathing Facilities	110~150 water	Yes	(65 / 7 / 11)	Unlikely	Unlikely	The Kapoho / Pohoiki area is not a very strong tourist destination. Local traffic may be significantly increased. Bathing facilities received a significant about of disapproval from the community (approximately 10%).
Spas / Onsen	110~150 water	Yes	(66 / 9 / 11)	Unlikely	Unlikely	The Kapoho / Pohoiki area is not a very strong tourist destination. Local traffic may be significantly increased. Spas / Onsen received a significant about of disapproval from the community (approximately 10%).
Swimming Pool	90~120 water	Yes	(67 / 4 / 16)	Somewhat	No	A swimming pool will not generate sufficient monies. There is an existing nearby County heated swimming pool that was constructed recently.
UHH Ag. Research Center	90~200 water	Yes	Not Applicable	Yes	Yes	It is unknown if UHH can secure funding for a research facility.

Note:
Shaded geothermal direct use enterprises represent potentially viable enterprises in the Kapoho / Pohoiki area.
*Ethanol distillation and biodiesel production were removed from further discussion and analysis because they are large consumers of heat and are more similar to power plants than the other direct use enterprises.

Aquaculture is a potential candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- Aquaculture is an expanding industry in the State of Hawaii based on reported Hawaii agricultural statistics (Hawaii, DBEDT August 2006).
- Aquaculture can take advantage of low temperature geothermally heated water.
- There is at least one company that uses geothermal water in the Kapoho / Pohoiki area to raise ornamental fish.
- The local tilapia market is expected to grow and could support Tilapia aquaculture farm development (Hopkins, K. 2006).
- Wastewater from tilapia ponds can be used for irrigating agricultural crops (Hopkins, K. 2006).

In addition to the above reasons, the community supports aquaculture in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Sixty-eight out of 92 questionnaire respondents support aquaculture, 5 disapprove, 13 are neutral, and 6 provided no response. Respondents felt that the use of geothermal heat for aquaculture is a "great idea" and has "great potential" "if done correctly". No negative comments were expressed.

The following significant barriers render aquaculture an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, and it was removed from further consideration:

- Studies are needed to determine which fish species can successfully be raised in Kapoho / Pohoiki geothermal waters.
- Fish raised in Hawaii would likely need to be exported in order to be profitable (Toda, 2006).

- The added cost and complexity of using geothermally heated water would need to be offset by the value added by accelerated fish growth.
- Accelerated growth rates can reportedly adversely affect fish flesh quality (Toda, 2006). Accelerated growth rates will need to be balanced against fish quality.
- Market development would need to be undertaken to promote tilapia in Hawaii and to remove the negative stigma surrounding tilapia.
- Tilapia farming is expected to be financially tough. Pond construction is estimated to cost between $1 and $2 per square foot in the Kapoho / Pohoiki area. Estimated annual tilapia production rate is 5,000 pounds per acre (Hopkins, K. 2006). The current whole tilapia price in Hawaii is near $2.00 per pound (Szyper 2005). An estimated capital cost of $50,000 to $100,000 with expected revenue of $10,000 leaves little room for labor, and does not appear to provide a very good return on investment.

2.4.2 Fruit / Vegetable Drying

Fruit and vegetable drying is a proven geothermal direct use enterprise that has experienced some degree of success. Drying is one of the oldest methods of preserving produce and is also a good alternative to throwing away excess produce or produce with minor imperfections.

Fruits and vegetables are considered part of Hawaii's diversified agriculture industry and their growth is encouraged by the State of Hawaii (Hawaii, DBEDT 2006). The Kapoho / Pohoiki area supports anthuriums, bananas, citrus, flowers, guavas, macadamia nuts, nursery products, papayas, tropical specialty fruits, and vegetables (USDA-NASS 2003). Some of the major tropical specialty fruit crops include noni, kawa, and cacao (Hopkins, M. 2006). Vegetable crops are mostly composed of lettuce, cabbage, and beans, which are infrequently dried.

Fruit and vegetable drying is a good candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- Diversified agriculture is supported by the State of Hawaii.
- Diversified agriculture is a major industry in the Kapoho / Pohoiki area.
- Diversified agriculture is increasing in the Kapoho / Pohoiki area, according to County personnel.
- Fruit and vegetable drying will help support a major existing industry in the Kapoho / Pohoiki area. Bananas, guavas, papayas, and tropical specialty fruits are good candidates for drying.

In addition to the above reasons, the community strongly supports fruit and vegetable drying in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Eighty-three out of 92 questionnaire respondents support fruit and vegetable drying, 1 disapproves, 4 are neutral, and 4 provided no response. Respondents felt that the use of geothermal heat with fruit and vegetable drying is a "great idea" with "so much potential". No negative comments were expressed.

The following significant barriers render fruit / vegetable drying an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, but it was retained for possible small scale development consideration because of its appeal and potential benefit to the community:

- Fruit / vegetable drying is labor intensive, Hawaii labor is expensive, and it would be difficult to compete with the global market. Hawaii would need to market its products towards niche demands, as local coffee is marketed, rather than trying to compete with global commodities.

- Available quantities and types of fruits / vegetables are limited. The Kapoho / Pohoiki area would need to produce enough fruit and vegetables to support a drying facility.
- Most types of vegetables grown in Hawaii are not typically dried.
- Previous studies have concluded that fruit drying would be marginally profitable at best. A geothermal direct use feasibility study for a Pahoa Geothermal Industrial Park completed in 1980 found that a papaya drying facility would be a risky, marginally profitable venture. A study completed in 1982 by Okahara, Shigeoka & Associates found that a papaya drying plant was not feasible at the time. This conclusion was based on high fruit costs, uncertain supply quantity of fruit for drying, and the large amount of fruit assumed to be required for profitability. A geothermal direct use demonstration project was conducted in 1988 at the NELHA facility near Pahoa. The demonstration project's report concluded that drying fruit is clearly technically feasible. However, a comparison of the report's 1988 costs versus today's retail prices indicates that it may not be economically successful. Today's retail prices, according to Amazon.com, are lower than the 1988 costs of producing dry fruit. This is in spite of free geothermal energy provided during the study, lower labor costs in 1988, and inflation between 1988 and today.

2.4.3 Greenhouses

Greenhouses are a proven geothermal direct use enterprise that has experienced tremendous success throughout the world. Greenhouses provide protection from the elements and can provide an ideal habitat for crops.

The diversified agriculture industry is encouraged by the State of Hawaii (Hawaii, DBEDT 2006) and has a large presence in the Kapoho / Pohoiki area. See Section 2.4.2 for a more detailed discussion of diversified agriculture in Hawaii.

Greenhouses are a good candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- Diversified agriculture is supported by the State of Hawaii.
- Diversified agriculture is a major industry in the Kapoho / Pohoiki area.
- Greenhouses are used by the local agricultural business community.
- The local agricultural business community has expressed interest in geothermal heat for greenhouses.
- A previous study concluded that greenhouses have the potential to be profitable. A geothermal direct use demonstration project was conducted by a local commercial greenhouse operator based nearby between 1988 and 1989 at the NELHA facility near Pahoa. The demonstration project's report concluded that a greenhouse bottom heating system is feasible and that the greenhouse operator was interested in commercial development of geothermal direct use as it pertains to bottom heating.

In addition to the above reasons, the community strongly supports greenhouses in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy-eight out of 92 questionnaire respondents support greenhouses, 1 disapproves, 3 are neutral, and 10 provided no response. Seventy-nine out of 92 questionnaire respondents support greenhouses: bottom soil heating, 1 disapproves, 3 are neutral, and 9 provided no response. Respondents felt that the use of geothermal heat with greenhouses is a "good idea" and "great for the nursery industry". No negative comments were expressed.

The following significant barriers must be overcome before geothermal direct use for greenhouses in the Kapoho / Pohoiki area can be developed:

- Hawaii has a subtropical environment.
- Increased crop production may not warrant relocating or expanding an agricultural business.
- Sufficient suitable acreage must be identified.

Based on the report's findings, greenhouses were determined to be potentially viable as geothermal direct use enterprises in the Kapoho / Pohoiki area and they were retained for possible commercial development consideration.

2.4.4 <u>Soil (Potting Media) Treatment</u>

Heat treatment of potting media is not a proven geothermal direct use enterprise but was recommended as a possible candidate.

The potted plant industry is part of the diversified agriculture industry and its growth is encouraged by the State of Hawaii (Hawaii, DBEDT 2006). See Section 2.4.2 for a more detailed discussion of diversified agriculture in Hawaii. The Island of Hawaii's potted plant industry is currently valued at approximately $34 million with a planned production increase of 70% over the next two years. The potted orchid industry is currently valued at over $20 million with an average production increase of 15% per year (Hopkins, M. 2006).

The potted plant industry requires sterile pathogen-free potting media. Heat treatment can pasteurize potting media and help prevent problems associated with plant disease and pests. It should be noted that heat treatment requirements are much stricter for soil than for potting media because of the high likelihood that soil harbors pests and diseases. Potting media used by the local potted plant industry includes cinder, hapuu (Hawaiian tree fern), peat moss, perlite, and coconut husks.

The local potted plant industry practice is to discard potting media after a single use. The reason for it is to protect against cross contamination of pests and diseases. Potted plants often require one or more transplants before they are market ready, and significant quantities of potting media can be disposed of during the transplant process (Hopkins, M. 2006). This may develop into a problem for the local potted plant industry should potting media prices increase. A significant amount of potting media is currently imported due to an insufficient supply in Hawaii, and worldwide demand for potting media may one day outpace supply. An increase in fuel prices and or potting media prices could have a detrimental effect on the local potted plant industry. The ability to recycle potting media could give the local industry a competitive edge in the global market.

Heat treatment (pasteurization and sterilization) of potting media is a good candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- Potting media is required of the diversified agriculture nursery products industry.
- There appears to be a demand for pasteurization / sterilization of potting media based on discussions with County and University personnel.
- Low cost heat treatment of potting media could give the local potted plant industry a competitive edge in the global market.
- A geothermal direct use demonstration project was conducted by a local nursery operator in 1990 at the NELHA facility near Pahoa. The demonstration project's report summarized that there is a real demand for pasteurized potting media and that geothermal energy can be used successfully as the treatment heat source.

In addition to the above reasons, the community strongly supports sterilization of potting media in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy-six out of 92 questionnaire respondents support sterilization of potting media, 2 disapprove, 7 are neutral, and 7 provided no response. Respondents felt that the use of geothermal heat with sterilization of potting media is a "great idea" and can potentially "cut costs for the nursery industry". No negative comments were expressed.

The following significant barriers must be overcome before geothermal direct use for pasteurization / sterilization of potting media in the Kapoho / Pohoiki area can be developed:

- Imported potting media costs may not justify pasteurizing / sterilizing and recycling potting media at this time.
- Recycling of potting media may have an adverse effect on the growth and quality of potted plants.

Based on the report's findings, pasteurization / sterilization of potting media was determined to be potentially viable as a geothermal direct use enterprise in the Kapoho / Pohoiki area and it was retained for possible commercial development consideration.

2.4.5 Seed Drying

Seed drying is very similar to fruit / vegetable drying. It is a good idea for similar reasons to fruit / vegetable drying, will face similar barriers, and was retained for possible small-scale development consideration because of its appeal and potential benefit to the community. The community strongly supports seed drying development in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy-seven out of 92 questionnaire respondents support seed drying development, 0 disapprove, 6 are neutral, and 9 provided no response. Respondents felt that the use of geothermal heat with seed drying is a "good idea" provided the seeds are not genetically modified. No negative comments were expressed.

2.4.6 Food Processing

Food processing is also similar to fruit / vegetable drying. It is a good idea for similar reasons to fruit / vegetable drying, will face similar barriers, and was retained for possible small-scale development consideration because of its appeal and potential benefit to the community. The community strongly supports food processing development in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy-five out of 92 questionnaire respondents support food processing, 3 disapprove, 6 are neutral, and 8 provided no response. Respondents felt that the use of geothermal heat with food processing is a "great idea". No negative comments were expressed.

2.4.7 Papaya Disinfection

Papaya disinfection is not a typical geothermal direct use enterprise but was considered a good candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- One method of papaya disinfection used by Island of Hawaii papaya processing plants utilizes hot air / steam for disinfection. Significant amounts of energy could be saved by using geothermally heated air / steam.
- The Kapoho / Pohoiki area supports a relatively stable papaya industry worth approximately $10 million per year papaya industry (Hawaii, Department of Research and Development, 2005).

In addition to the above reasons, the community supports papaya disinfection in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy out of 92 questionnaire respondents support papaya disinfection, 4 disapprove, 8 are neutral, and 10 provided no response. Respondents felt that the use of geothermal heat with papaya disinfection is a "great idea" that will not have the perceived "stigma of irradiation", a competing treatment method. No negative comments were expressed.

The following significant barriers render papaya disinfection an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, but it was retained for possible small-scale development because of its potential benefit to the agricultural business community:

- Discussions with Tropical Hawaiian Products and Diamond Head Papaya reveal that moving their existing papaya processing plant to Kapoho / Pohoiki would be prohibitively expensive. Tropical Hawaiian Products added that Kapoho / Pohoiki is too far from their distribution points. Both processing plants indicated that they would not be interested in relocating.
- The existing Island of Hawaii papaya processing plants are not operating at capacity (Hopkins, M. 2006). It will probably be difficult to justify the relocation or construction of a papaya processing plant.

2.4.8 <u>Community Commercial Kitchen</u>

A community kitchen is not a typical geothermal direct use enterprise and the benefits geothermal heat can provide is limited. Geothermally heated hot water can be used for washing dishes and for sanitation purposes. Food, however, would still likely need to be prepared using conventional heat sources such as electricity or gas.

There are several community kitchens on the Island of Hawaii. There are three incubator kitchens located in Honokaa, Papaaloa, and Hakalau. All of them are available for rent and all of them have difficulty generating enough revenue to be self-sustaining. There is one production kitchen located in Hilo that was formerly used as a community kitchen but is currently being used by the Hawaii County Economic Opportunity Council. There is one community kitchen located in Cooper Center in Volcano Village. It reportedly has strong community support and is financially self-sustaining. There is also one community kitchen located in Kohala that is reportedly used infrequently. The kitchens were funded by a variety of methods and are operated differently (Horike 2006). The University of Hawaii at Manoa College of Tropical Agriculture & Human Resources completed a paper on two of the incubator kitchens entitled *Some Costs and Considerations for Establishing an Entrepreneurial Community Shared-Use Kitchen or "Test-Kitchen Incubator" (The Examples of the Hamakua Incubator Kitchen & Crafts and the Honokaa Ohana Kitchen Project)*. The paper found that careful planning, lots of coordination, strong community support, and a significant pool of motivated prepared entrepreneurs are required for success.

In spite of the fact that a community kitchen would only be able to take limited advantage of geothermal heat in the form of hot water for washing dishes and sanitation, it could support other direct use enterprises. Produce drying and food processing, for instance, need a commercial kitchen for food preparation.

A commercial kitchen would be great for the Kapoho / Pohoiki area community for the following reasons:

- The community could use the commercial kitchen to produce goods to sell commercially. It has the ability to help start new businesses.
- It could help established small businesses reduce operating costs.
- It could help support other food related geothermal direct use enterprises.

In addition to the above reasons, the community strongly supports a community commercial kitchen in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy-four out of 92 questionnaire respondents support a community commercial kitchen, 2 disapprove, 8 are neutral, and 8 provided no response. Respondents felt that the use of geothermal heat with a community commercial kitchen is a "great idea". No negative comments were expressed.

The following significant barriers may render community kitchens an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, but it was retained for possible development consideration because of its appeal and potential benefit to the community:

- A community kitchen is not a viable geothermal direct use enterprise in itself. It is only viable if there are other geothermal direct use enterprises that require a commercial kitchen.
- A source of funding to design and construct a community kitchen needs to be identified.
- A community kitchen requires strong community support to be successful. It is not clear that there would be sufficient demand for a community kitchen by the Kapoho / Pohoiki community.
- Other Island of Hawaii community kitchens have met with very limited success.
- There are other commercial kitchens that the Kapoho / Pohoiki community can use including schools, churches, and some private establishments.

2.4.9 Drying Concrete Blocks

Drying (curing) concrete blocks is a proven geothermal direct use enterprise that has experienced success. Drying concrete blocks can require significant amounts of heat and is a good candidate for geothermal direct use.

Additionally, the community supports drying concrete blocks in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Sixty-seven out of 92 questionnaire respondents support drying concrete blocks, 5 disapprove, 11 are neutral, and 9 provided no response. Respondents felt that the use of geothermal heat with a concrete block drying plant is a "great idea". Some were concerned and requested additional information about the process.

The following significant barriers render drying concrete an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, and it was removed from further consideration:

- Most of the current construction is occurring on the West side of the island and transportation costs from Puna are high.
- There is one competing concrete block manufacturing company located in West Hawaii.
- Drying concrete blocks may not be supported by the community because it is an industrial type of business that will increase heavy vehicle traffic in the area.

2.4.10 Drying Fish

Drying fish is a proven geothermal direct use enterprise in colder areas of the world such as Iceland. Drying is a popular means of preserving and improving the shelf life of fish. Air is heated to about 75-85 degrees F and fish are allowed to dry in 20~50% relative humidity air.

Fishing is a sizeable local industry in Hawaii and produced approximately $44.846 million of commercial fish in 2002. Of that amount, approximately 1.5% or $0.668 million of commercial fish in the State of Hawaii were landed at Pohoiki Bay (Hawaii, Department of Research and Development 2005).

Drying fish is a good candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- There is a significant amount of fish landed nearby at Pohoiki Bay.
- Dried fish is part of the local diet.
- Geothermal heat is a good alternative to air drying or electric dehydrators.

In addition to the above reasons, the community supports drying fish in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Sixty-eight out of 92 questionnaire respondents support a fish drying operation, 6 disapprove, 8 are neutral, and 10 provided no response. Respondents felt that the use of geothermal heat to dry fish is a "good idea". No negative comments were expressed.

The following significant barriers may render fish drying an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, but it was retained for possible small-scale development consideration because of its appeal and potential benefit to the community:

- The price of geothermally dried fish would need to be higher than the price of fresh fish to be viable.
- It is unknown whether the quantity of fish landed at Pohoiki Bay is sufficient to support a geothermal fish drying facility.

2.4.11 Ethanol Distillation

Ethanol distillation is a relatively undemonstrated geothermal direct use enterprise that has experienced limited success. Ethanol helps to reduce dependence on fossil fuels (i.e., gasoline) and has gained popularity in the United States. Since April 2, 2006, the State of Hawaii requires that a minimum of 85% of the gasoline sold in Hawaii contain 10% ethanol. The law was enacted to reduce the State's dependence on imported crude oil and to promote local ethanol production.

Ethanol distillation requires significant amounts of steam and electricity and geothermal energy seems like a natural fit. One ethanol plant utilizing geothermal heat was constructed in Wabuska, Nevada and began ethanol production in 1980 (Ultrasystems Engineers and Constructors, Inc. 1981). The plant operated for approximately 2-3 years before being converted to a geothermal power plant. The price of ethanol fell and it was no longer economically feasible to produce ethanol (Sunrise Sustainable Resources Group 2003).

Locally, a study was completed in 1980 to determine the feasibility of an ethanol plant using geothermal heat to be located in the Kapoho / Pohoiki area. The study was completed at a time when the sugar industry was strong in Hawaii. Sugar is one of the two most common feedstocks used to produce ethanol. The study concluded that it is unclear whether an ethanol plant using geothermal heat would be feasible, and that there would be significant risks. Risks include the availability of the geothermal resource, social impact, labor and economic impact, environmental, and financial related issues.

The following significant barriers must be overcome before geothermal direct use for ethanol distillation in the Kapoho / Pohoiki area can be developed:

- Electricity production is both a proven and profitable geothermal steam application on the Island of Hawaii. Ethanol distillation may need to be financially more attractive than power production to be feasible unless the local electricity company decides against purchasing additional electric power produced by geothermal heat.
- There are competing ethanol plants currently being developed statewide. It is unclear whether there will be sufficient demand to

warrant additional ethanol production. The 2003 State of Hawaii ethanol demand was estimated to be 40.2 million gallons with 6.7 million gallons representing the Island of Hawaii's ethanol demand (Stillwater 2003). According to DBEDT Notices of Construction of Ethanol Production Facilities, approximately 60 million gallons of ethanol production capacity, 10 million gallons on the Island of Hawaii, is under development as of July 2006 (DBEDT 2006).

- It is unclear whether the community would accept a large industrial type application in their neighborhood. Some residents have expressed concerns in previous public meetings of enterprises driven by "outsiders".
- Ethanol was only marginally supported by the community for development in the Kapoho / Pohoiki area (56 out of 92 questionnaire respondents). Respondents were concerned with ethanol "not being a very efficient fuel", and wanted more information on production methods despite it offsetting the use of fossil fuels.

In spite of the tremendous potential of using geothermal heat for ethanol distillation, it was removed from further consideration because its feasibility can be evaluated independent of this report. An ethanol distillation plant, similar to a power plant, requires large quantities of high temperature heat and can justify the necessary geothermal exploratory and development costs. The other geothermal direct use enterprises being considered by this feasibility study are relatively small consumers of low temperature heat and cannot justify the same amount of exploratory and development costs.

2.4.12 Biodiesel Production

Producing biodiesel is not a typical geothermal direct use enterprise but could be a good candidate for the following reasons:

- The Kapoho / Pohoiki area is predominantly agricultural and presumed to have a significant percentage of diesel vehicles.
- The community supports biodiesel production.
- A local business has expressed interest in geothermal heat for a biodiesel plant.

The following significant barriers must be overcome before geothermal direct use for biodiesel production in the Kapoho / Pohoiki area can be developed:

- Feedstock needs to be imported to the Island of Hawaii.
- Biodiesel was only somewhat supported by the community for development in the Kapoho / Pohoiki area (62 out of 92 questionnaire respondents). Respondents were concerned and wanted more information on production methods.

Based on the report's findings, biodiesel production was determined to be potentially viable as a geothermal direct use enterprise in the Kapoho / Pohoiki area and it was retained for possible commercial development consideration.

2.4.13 Ice Plant, Cold Storage and or Refrigeration

Ice making, cold storage, and refrigeration are proven geothermal direct use enterprises that have experienced some success. Ice could help the local fishing industry and specifically the fisherman using Pohoiki Bay. Approximately 1.5% or $0.668 million of the State's commercial fish catch was landed at Pohoiki Bay in 2002 (Hawaii, Department of Research and Development 2005). Fishermen must currently haul ice from Hilo and reportedly lose up to 20% of the ice due to melting (Hirai 1983). Cold storage and refrigeration could help temporarily store perishables including produce and flowers produced in the Kapoho / Pohoiki area. Cold water could be used to cool "refrigerated" greenhouses.

Ice making, cold storage, and refrigeration are good candidates for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- There is a significant amount of fish landed at the nearby Pohoiki Bay.
- It could help support other local industries.

In addition to the above reasons, the community strongly supports ice making, cold storage, and refrigeration in the Kapoho / Pohoiki area as geothermal direct use enterprises. Seventy-three out of 92 questionnaire respondents support ice making, cold storage, and refrigeration, 3 disapprove, 5 are neutral, and 11 provided no response. Respondents felt that the use of geothermal heat to produce ice or cooling is a "great idea". No negative comments were expressed.

The following significant barriers render ice making, cold storage, and refrigeration unlikely candidates as viable geothermal direct use enterprises in the Kapoho / Pohoiki area, and they were removed from further consideration:

- There is insufficient heat available to effectively make ice, and only marginally enough heat to make cold water for cooling. Absorption type chillers require 200+ degree F heat to produce cooling. Generally, the higher the available temperatures, the greater the cooling capability. Maximum anticipated geothermal temperatures are likely to be below 200 degrees F. Only one custom chiller manufacturer was identified whose chillers could make flake ice with 190 degree F water. Three of the major chiller manufacturer's chillers could barely make cold water with 190 degree F water.
- The demand for ice and cooling may not justify installing expensive mechanical equipment. It may be more cost effective to purchase and

transport ice from Hilo. Unless there is a sustained shortage of ice on the Island of Hawaii, an additional ice plant may not be able to claim a sufficient share of the market from existing ice-making businesses.

2.4.14 Laundromat

A laundromat is not a typical geothermal direct use enterprise but could prove viable in the Kapoho / Pohoiki area for the following reasons:

- There are only two laundromats in Pahoa based on a 2006 search of the telephone directory.
- Laundromats can consume large quantities of hot water.

In addition to the above reasons, the community supports laundromats in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Sixty-eight out of 92 questionnaire respondents support laundromat development, 4 disapprove, 11 are neutral, and 9 provided no response. Respondents felt that the use of geothermal heat with laundromats is a "good idea", that more laundromats are needed in Puna, and that geothermal heat will help cut costs. No negative comments were expressed.

The following significant barriers may render laundromat operation an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, but it was retained for possible small-scale development consideration because of its appeal and potential benefit to the community:

- The Kapoho / Pohoiki area may not be growing fast enough to warrant another laundromat.
- A geothermal laundromat would likely be located outside of the Pahoa town limits. It is unknown whether this would affect customer traffic.
- Laundromats are a large consumer of water and large producer of wastewater, which would need proper disposal.

2.4.15 Lumber Kilns

Lumber drying is a proven geothermal direct use enterprise that has experienced some success. Kilns afford wood-workers the ability to dry wood quickly and add value to the lumber.

Local hardwood and hardwood furniture are very popular and can command premium prices. Local wood artists / workers currently depend on air drying or kilns to dry their wood to the proper equilibrium moisture content. Interest was received from the wood-working community regarding using geothermal heat for lumber kilns. The major concern raised was transportation costs.

A Hawaii hardwood market study was completed in 2004 by the Hawaii Agriculture Research Center for the Department of Land and Natural Resources. The study found that there is significant demand for Hawaiian grown woods but there are insufficient lumber drying facilities to produce consistent quality lumber. The study estimates that approximately 500,000 to 800,000 board feet of wood are produced annually on the Island of Hawaii with the State importing approximately 7,000,000 to 10,000,000 board feet of wood annually. The study concluded that there is potential for Hawaiian hardwood growth provided there is sufficient forest management and proper marketing.

Lumber drying is a good candidate for geothermal direct use development in the Kapoho / Pohoiki area for the following reasons:

- Local hardwoods serve a niche market that does not have to compete in the world commodity market.
- There is a significant "untapped" local lumber market that could be developed with a cost effective lumber drying kiln.

- The local wood-working business community has expressed significant interest and would like to explore and or pursue geothermally heated kilns. Businesses may be able to expand with an economical means to dry lumber.
- A previous study concluded that lumber drying has the potential to be profitable. A geothermal direct use demonstration project was conducted by King Koa in 1988 at the NELHA facility near Pahoa. The report concluded that using geothermal heat to dry lumber is both technically and economically feasible.

In addition to the above reasons, the community supports lumber kiln development in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Seventy out of 92 questionnaire respondents support lumber kiln development, 4 disapprove, 10 are neutral, and 8 provided no response. Respondents felt that the use of geothermal heat with lumber kilns is "great" provided that lumber is "sustainably harvested". No negative comments were expressed.

The following significant barriers must be overcome before geothermal direct use for lumber drying in the Kapoho / Pohoiki area can be developed:

- It is uncertain whether the net savings of replacing utility heating with geothermal heat and added transportation costs would warrant relocating established businesses.
- There are competing methods of drying including air drying and exporting lumber to the mainland for conventional drying.

Based on the report's findings, lumber drying was determined to be a potentially viable geothermal direct use enterprise in the Kapoho / Pohoiki area and it was retained for possible commercial development consideration.

2.4.16 Rumber® Production

Rumber® is a product manufactured of recycled tires and plastics. Rumber® can be made into a variety of products including flooring beds for trucks and trailers, docks and seawalls, and various custom products. Rumber® is not a typical geothermal direct use application but may be a good candidate for development in the Kapoho / Pohoiki area for the following reasons:

- Rumber® can help reduce the amount of material sent to the local landfills while creating new jobs and products.
- There is a growing interest in using recycled building materials.

In addition to the above reasons, the community supports Rumber® manufacturing in the Kapoho / Pohoiki area as a geothermal direct use enterprise. Sixty-three out of 92 questionnaire respondents support Rumber® manufacturing, 9 disapprove, 11 are neutral, and 9 provided no response. Respondents felt that the use of geothermal heat with Rumber® manufacturing is an "interesting and great recycling idea". Some were concerned about the possible environmental impact and requested additional information about the manufacturing process.

The following significant barriers render Rumber® manufacturing an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, and it was removed from further consideration:

- Most of the used tires and plastics are located on Oahu. Sufficient raw materials may not exist on the Island of Hawaii, and transportation costs to Kapoho / Pohoiki would be significant.
- The market for Rumber® products is unproven in Hawaii.

2.4.17 Soap Making

Soap making was removed from further consideration as a viable geothermal direct use candidate in the Kapoho / Pohoiki area because of the following reasons:

- It is not believed that soap making would not create many jobs or significant income.
- Transportation costs would likely offset any energy savings.

2.4.18 Bathing Facilities (Public or Private) / Spas & Onsen

Bathing facilities, spas, and onsen are some of the first and oldest direct uses of geothermal heat worldwide. Native Americans, Europeans, Asians, Hawaiians and early settlers have all taken advantage of naturally heated springs, ponds, and vents in their respective areas for rest and relaxation.

Some of the most prized spas / onsen have naturally heated, mineral rich water. Individuals often have preferences regarding specific water quality and mineral content. On Oahu, the Ihilani Resort and Spa uses heated ocean water in one of their Spa water therapy packages. On the Island of Hawaii, volcanically heated ponds at Ahalanui Beach Park are promoted for rest and relaxation. Also on the Island of Hawaii, near Pahoa, naturally occurring steam vents are one of the amenities provided at the Steam Vent Inn.

A geothermal spa study was prepared by GeothermEx, Inc. in 2000 for the purpose of assessing "opportunities for developing onsen facilities in Hawaii and to provide a convenient summary of information for potential onsen developers". The report discusses characteristics of good spas, prospective areas for onsen development, and marketing considerations. One of the prospective areas identified for onsen development is near the Puna coast. Although the report did not assess the feasibility of onsen development, it hinted that onsen would be only one component necessary for a development of an onsen resort. It also hinted that onsen development would need to occur relatively close to the coast where elevations were lower and well drilling costs could be minimized.

Bathing facilities, spas and onsen are good candidates for geothermal direct use development in the Kapoho / Pohoiki area because they could help support Hawaii's strong tourist industry.

The following significant barriers may render bathing facilities, spas, and onsen an unlikely candidate as a viable geothermal direct use enterprise in the Kapoho / Pohoiki area, and it was removed from further consideration:

- The Kapoho / Pohoiki area is not a very strong tourist destination.
- Local traffic may be significantly increased.
- Bathing facilities, spas and onsen were supported by the community for development in the Kapoho / Pohoiki area (65 out of 92 questionnaire respondents for bathing facilities and 66 out of 92 questionnaire respondents for Spas/Onsen). However, there was also significant disapproval (7 out of 92 respondents for bathing facilities and 9 out of 92 respondents for Spas/Onsen) as compared with the other geothermal direct use enterprises considered. One respondent was concerned that vanity type uses of geothermal heat are a bad idea.

2.4.19 Swimming Pool

Heating swimming pools is a proven geothermal direct use enterprise that has experienced success. In spite of Hawaii's warm climate, there are three municipal and at least five private heated swimming pools located on the Island of Hawaii.

Kapoho / Pohoiki residents would probably welcome a heated swimming pool; naturally heated ponds along the coast are very popular. However, a municipal heated swimming pool was recently constructed in Pahoa near prospective geothermal direct use enterprise park sites and it was removed from further consideration.

2.4.20 Additional Geothermal Direct Use Enterprises

There were a number of geothermal direct use enterprises that were suggested after the questionnaires were distributed including the following:

- Homeopathy
- Splitting bamboo with steam
- Steam for pulping plant (non-wood or recovered paper)
- Treating hazardous chemicals
- Polyurethane foam concrete block system
- University of Hawaii at Hilo College of Agriculture geothermal direct use research center
- Hot water treatment for coqui eradication

Homeopathy is similar to spas and will face similar challenges. Splitting bamboo and a pulping plant are unlikely to become viable geothermal direct use enterprises in the Kapoho / Pohoiki area because steam will most likely be unavailable. Treating hazardous chemicals would probably face strong opposition from the Kapoho / Pohoiki community. Polyurethane foam concrete block manufacturing plants may be a possibility but may face some opposition from the community based on initial comments received by the 2005 Working Group. A University of Hawaii at Hilo (UHH) College of Agriculture geothermal direct use research center has the potential of becoming a viable geothermal direct use enterprise in the Kapoho / Pohoiki area. A UHH geothermal direct use research center would be able to support, promote, troubleshoot, and optimize other geothermal direct use enterprises related to agriculture. In effect they will be able to provide necessary research and development to maximize the success of agricultural businesses using geothermal heat. Hot water treatment for coqui eradication also has the potential of becoming a viable geothermal direct use enterprise in the Kapoho / Pohoiki area especially if located near a potted plant nursery.

2.5 SUMMARY OF GEOTHERMAL DIRECT USE ENTERPRISES

In summary, it appears that there are a sufficient number of potentially viable geothermal direct use enterprises to warrant development of geothermal direct use in the Kapoho / Pohoiki area. Most of the potential geothermal direct use enterprises were removed from further consideration because they were determined to be non viable or unlikely to be viable. One of the geothermal direct use enterprises considered, ethanol distillation, was removed because it was determined to be a high temperature geothermal direct use application that is similar to power plants in terms of its large consumption of high temperature heat. The remaining enterprises were determined to be low temperature geothermal direct use enterprises that are relatively small consumers of heat. It is hoped that high temperature geothermal direct use enterprises could provide a source of waste heat for low temperature geothermal direct use enterprises, should they be developed. Nine geothermal direct use enterprises were determined to have high community appeal and to be potentially beneficial to the community including fruit drying, seed drying, food processing, papaya disinfection, community commercial kitchen, drying fish, laundromat, university research center, and hot water treatment for coqui eradication. These geothermal direct use enterprises are believed to either consume small quantities of heat or are not anticipated to create significant revenue but were retained for possible small-scale development consideration. Four geothermal direct use enterprises were determined to be potentially viable including greenhouses, pasteurization of potting media, biodiesel production, and lumber kilns and were retained for possible commercial development consideration.

CHAPTER 3 – GEOTHERMAL HEAT RESOURCES

3.1 INTRODUCTION

This chapter will discuss the methodology used to identify geothermal heat resources in the Kapoho / Pohoiki area for direct use development. The first step was to acquire some basic understanding of the nature of geothermal resources located beneath the Kapoho / Pohoiki area. The second step was to briefly evaluate all of the existing geothermal and water wells located in the Kapoho / Pohoiki area. The third step was to identify and locate potentially viable geothermal heat sources based on previous studies, existing geothermal and water well data, and expert testimony. The fourth step was to eliminate all non-viable geothermal heat sources.

It was concluded that the only potentially economically viable access to geothermal heat in the Kapoho / Pohoiki area would be through a future application of high temperature geothermal heat. The targeted source of heat would be spent geothermal fluids that the future application would have injected into the ground as waste heat. PGV was removed from consideration as a potential source of heat because of planned power plant modifications that are expected to reduce the amount of available waste heat and increase the chance of encountering scaling problems. Existing and new wells were removed from consideration because of high anticipated costs.

3.2 NATURE OF THE GEOTHERMAL RESOURCES IN THE KAPOHO / POHOIKI AREA

Understanding the nature of geothermal resources significantly improves any chance to identify, locate, and access them. There have been a number of studies and reports describing the extent of geothermal resources in the Kapoho / Pohoiki area, their theorized locations, and their energy flow dynamics. Most of the reports are based on a combination of Puna geothermal resource data, geothermal resource models, and behavior of other geothermal resource around the world. In spite of the considerable research and studies undertaken, geothermal resources in the Kapoho / Pohoiki area continue to be poorly understood because of limited available data and the area's unique geology / hydrology.

According to a report entitled *A Conceptual Model of Shallow Groundwater Flow Within the Lower East Rift Zone of Kilauea Volcano, Hawaii* by Dr. Elizabeth Novak and Dr. Donald Thomas, the Puna geothermal resource appears to be located along the extent of Kilauea's East Rift Zone (KERZ). KERZ runs in a northeasterly direction between Puu Honuaula and Cape Kumukahi in the lower Puna area. The extent of the geothermal resource appears to be bound to the north and south by dikes that run parallel to the KERZ. These nearly vertical dikes are permeable along their planar direction, but nearly impermeable perpendicular to their planar direction. The upper portion of the geothermal resource appears to be bound by a 500-meter (1,640 feet) thick transition layer that begins approximately 750 meters (2,461 feet) below sea level. The Puna geothermal resource is composed of a combination of heated meteoric and sea water, in mixed vapor / liquid fluid form, up to 375 degrees C (707 degrees F) in temperature.

Fractures located throughout the KERZ provide a conduit through which geothermally heated fluid can migrate in an upward direction. Some of these fractures extend through the transition zone and allow steam and / or hot water to migrate to the top of the water table. Once the heated fluid reaches the top of the water table, it will generally mix with the cooler groundwater and travel in a horizontal direction until it is finally discharged along the coastline as warm water. Well water temperatures have been found to approach up to 100 degrees C (212 degrees F) near fractures where geothermally heated fluid can migrate into the water table.

3.3 EXISTING WELLS IN THE KAPOHO / POHOIKI AREA

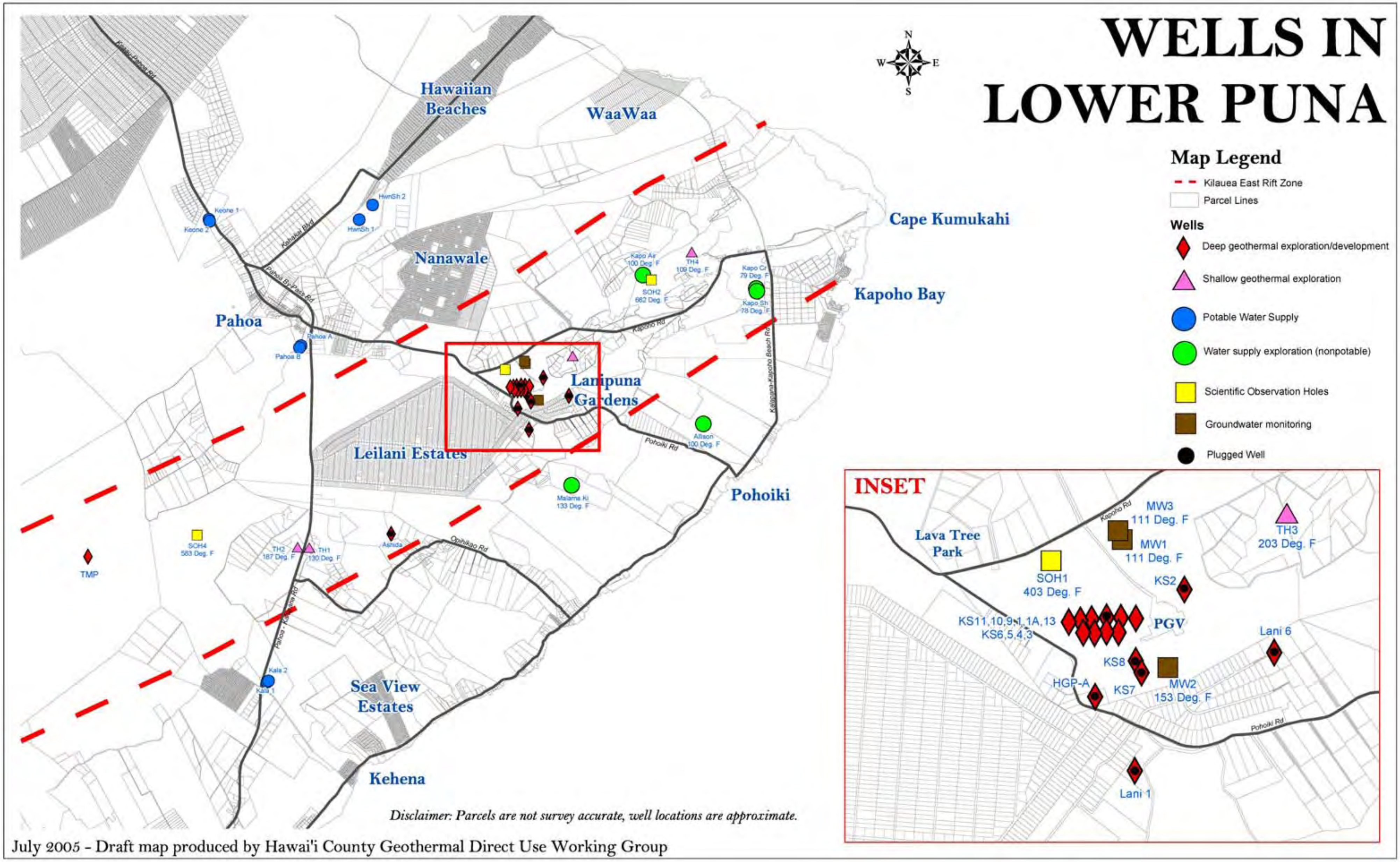
There have been a number of wells drilled in the Kapoho / Pohoiki area over the past 50 years in search of potable water and geothermally heated fluid. Data collected from these wells have helped scientists understand the nature of the Puna geothermal resource, and also provides valuable insight that will help in the exploitation of geothermal heat necessary for direct use. Existing wells range in depth from a few meters to a couple thousand meters. See Figure 3-1 and Table 3-1 for a map and associated data of wells located in the lower Puna area assembled by the 2005 Working Group.

The existing wells have been separated into two groups of wells consisting of shallow wells and deep wells. Shallow wells were arbitrarily considered to be wells that do not extend into or beyond the transition zone that begins approximately 750 meters (2,461 feet) below mean sea level (msl). Deep wells were arbitrarily considered to be wells that extend into or beyond (below) the transition zone. Shallow wells were further separated into subgroups consisting of water supply exploration / production wells (potable and nonpotable), shallow geothermal exploration wells, and groundwater monitoring wells.

3.3.1 Shallow Wells in the Kapoho / Pohoiki Area

There were 13 water supply exploration / production wells drilled in the Kapoho / Pohoiki area between 1960 and 1977 that extend up to 15 meters (49 feet) below msl. Eight of the wells have a potable water supply and 5 of the wells have a nonpotable water supply. Six of the potable water wells are located to the north of the KERZ, 0 are located in the KERZ, and 2 are located to the south of the KERZ. None of the nonpotable water wells are located to the north of the KERZ, three are located in the KERZ, and 2 are located to the south of the KERZ. Maximum recorded potable and nonpotable well water temperatures ranged between 22 and 24 degrees C (72 and 75

GEOTHERMAL HEAT RESOURCES
FIGURE 3-1: EXISTING KAPOHO / POHOIKI AREA WELLS



GEOTHERMAL HEAT RESOURCES
TABLE 3-1: EXISTING KAPOHO / POHOIKI AREA WELL DATA

Well Group	Abbr	Map Key	ID #	Latitude	Longitude	Elevation (m)	Elevation (ft)	Depth (m)	Depth (ft)	Max Temp (deg C)	Max Temp (deg F)	Date Drilled	Use/Status
Potable water supply		blue											
Hawaiian Shores 1	HwnSh 1	circle	3185-01	193113	1545558	122.5	402	135.9	446	22	71	1964	domestic
Hawaiian Shores 2	HwnSh 2		3185-02	193126	1545544	115.8	380	131.1	430			1971	domestic
Keauohana 1 (Kalapana)	Kala 1		2487-01	192456	1545719	229.2	752	244.4	802	24	75	1961	municipal
Keauohana 2 (Kalapana)	Kala 2		2487-02	192457	1545718	229.2	752	244.8	803	24	75	1970	municipal
Keonepoko Nui	Keone		3188-01	193105	1545803	183.8	603	198.1	650	24	75	1977	municipal
Pahoa Battery 2A	Pahoa A		2986-01	192925	1545646	214.9	705	230.1	755	24	75	1960	municipal
Pahoa Battery 2B	Pahoa B		2986-02	192924	1545647	216.7	711					1960	municipal
Water supply exploration (nonpotable)		green											
Allison (Pohoiki)	Allison	circle	2881-01	192819	1545110	40.2	132	42.7	140	38	100	1973	other
Kapoho Airstrip	Kapo Air		3081-01	193024	1545159	87.5	287	102.7	337	38	100	1961	unused
Kapoho Crater	Kapo Cr		3080-01	193016	1545021	11.6	38	14	46	25	77	1965	unused
Kapoho Shaft	Kapo Sh		3080-02	193017	1545021	11.6	38	14	46	25	77		unused
Malama Ki	Malama Ki		2783-01	192728	1545301	83.5	274	97.2	319	54	129	1962	unused
Pulama	Pulama		2102-01	192107	1550212	70.1	230	76.2	250	26	78	1963	unused
Groundwater monitoring		brown											
MW1	MW1	square	2983-01	192908	1545339	185.9	610	219.5	720	44	111	1990	other
MW2	MW2		2883-07	192836	1545330	179.2	588	195.1	640	67	153	1991	observation
MW3	MW3		2983-02	192910	1545340	185.9	610	219.5	720	44	111	1991	other
Scientific Observation Holes		orange											
SOH1	SOH1	square		192908*	1545350*			1684.3	5526	209	408	1991	monitoring
SOH2	SOH2			193024*	1545200*			2073.2	6802	349	661	1991	monitoring
SOH4	SOH4			192700*	1545820*			2000.1	6562	302	576	1990	monitoring
Shallow geothermal exploration		pink											
Puna Thermal TH1	TH1	triangle	2686-01	192634	1545646	307.5	1009	66.1	217	55	130	1961	unused
Puna Thermal TH2	TH2		2686-02	192633	1545648	315.5	1035	169.5	556	86	187	1961	unused
Puna Thermal TH3	TH3		2982-01	192913	1545255	171.6	563	210.3	690	95	203	1961	unused
Puna Thermal TH4	TH4		3081-02	193039	1545119	76.2	250	88.4	290	43	109	1961	unused
Deep geothermal exploration/development		red											
Ashida 1	Ashida	diamond	2685-01	192659	1545532	244.4	802	2529.8	8300	288	550	1980	plugged
HGP-A	HGP-A		2883-01	192831	1545343	182.9	600	1967.5	6455	368	680	1976	plugged
KS 1	KS1		2883-03	192847	1545339	188.7	619	2222	7290	343	650	1981	plugged
KS 1A	KS1A		2883-06	192848	1545337	189	620	1982.7	6505	354	670	1985	geo injection
KS 2	KS2		2883-04	192855	1545322	219.2	719	2622.8	8605	>354	>670	1982	plugged
KS 3	KS3		2883-09	192843	1545339	186.8	613	2257.3	7406	>351	>664		geo injection
KS 4	KS4							2071.1	6795	327	620		geo injection
KS 7	KS7							511.5	1678	>260	>500		plugged
KS 8	KS8		2883-11	192848	1545328	192	630	1060.1	3478	377	711		plugged
KS 9	KS9		2883-13	1928	15453			1391.1	4564	342	647		geo production
KS 10	KS10							1549.3	5083				geo production
Lanipuna 1	Lani 1		2883-02	192816	1545333	182.9	600	2557	8390	221	429	1981	plugged
Lanipuna 6	Lani 6		2883-05	192844	1545304	182.9	600	1510.6	4956	168	335	1981	plugged

References:
GeothermEx, Inc. "Annual Report: Geothermal Resources Assessment." Prepared for Dept. of Business, Economic Development and Tourism; December 1994.
Janik, Cathy J. et al. "Chemistry of spring and well waters on Kilauea Volcano, Hawaii, and vicinity." U.S. Department of the Interior, U.S. Geological Survey. 1994.
*SOH latitude and longitude estimated from GeothermEx, Inc. "Update of the Statewide Geothermal Resource Assessment." Prepared for DBEDT, June 2000.

degrees F), and between 25 and 38 degrees C (77 and 100 degrees F) respectively.

There are 4 shallow geothermal exploration wells that were drilled in the KERZ in 1961. The wells were designated TH-1, TH-2, TH-3 and TH-4, otherwise known as GTW-1, GTW-2, GTW-3 and GTW-4. Wells TH-1 and TH-2 are very shallow and never reached the water table. Wells TH-3 and TH-4 extend up to 39 meters (128 feet) below msl. Maximum recorded well water temperatures ranged between 43 and 95 degrees C (109 and 203 degrees F).

There are 3 shallow monitoring wells that were drilled in the KERZ, adjacent to PGV, between 1990 and 1991. The wells were designated MW-1, MW-2, and MW-3. All of the wells extend up to 35 meters (115 feet) below msl and are used primarily for monitoring purposes. Maximum recorded well water temperatures ranged between 44 and 67 degrees C (111 and 153 degrees F).

The following conclusions were drawn based on the collected data of shallow geothermal wells located in the Kapoho / Pohoiki area:

- Shallow geothermally heated water appears to be located in and to the south of the KERZ. No shallow geothermally heated water appears to be located to the north of the KERZ.
- Salt water appears to be geothermally heated, rise to the top of the water table, and mix with the fresh basal water in and to the south of the KERZ.
- The maximum temperature of shallow geothermally heated water appears to be 100 degrees C (212 degrees F).

3.3.2 Deep Wells in the Kapoho / Pohoiki Area

There are 13 deep geothermal exploration / production wells that were drilled in the Kapoho / Pohoiki area since 1976. All of the wells range in depth between 868 and 2,404 meters (2,848 and 7,887 feet) below msl except one. Well KS-7 was damaged during drilling and subsequently capped and abandoned. Maximum recorded well fluid temperatures ranged between 168 and 377 degrees C (334 and 711 degrees F). Two of the wells are currently used to produce electricity, 3 of the wells are used for injection, and 8 of the wells have been plugged.

There are 3 deep scientific observation holes that were drilled in the Kapoho / Pohoiki area in 1990 and 1991 to study the geology of the KERZ. Wells range in depth between 1,498 and 1,951 meters (4,915 and 6,401 feet) below msl. Maximum recorded well fluid temperatures ranged between 209 and 349 degrees C (408 and 660 degrees F). All three of the wells are currently used for monitoring.

The following conclusions were drawn based on the collected data of deep geothermal wells located in the Kapoho / Pohoiki area:

- There are high temperature geothermally heated fluids located in the KERZ.
- High temperature, sustainable production geothermal resources have been found at a depth between 1,200 and 1,785 meters (3,937 and 5,856 feet) below msl.

3.4 IDENTIFY POSSIBLE GEOTHERMAL RESOURCES

It has been demonstrated that there are shallow and deep geothermal resources in the Kapoho / Pohoiki area along the KERZ through the efforts of geothermal exploration over the years, and through the development of PGV's geothermal power plant in 1993. There are basically five means to access geothermal resources in the Kapoho / Pohoiki area including utilizing existing wells, drilling new wells, extracting heat from hot dry rock, acquiring "waste heat" from PGV's geothermal power plant, and acquiring "waste heat" from a future geothermal application.

3.4.1 Geothermal Resources – Existing Wells

One of the biggest issues with utilizing geothermal resources is successfully identifying a production resource. According to the *Geothermal Direct-Use Engineering and Design Guidebook* edited by Dr. John Lund, the success rate of identifying a geothermal production well in a well-explored area approaches 80% at best. The success rate can be expected to fall to 10-20% in relatively unexplored areas. Such uncertainty poses a significant financial risk to entities interested in geothermal exploration and development. Unused existing geothermal wells present an opportunity to avoid costly investigative studies and to minimize financial risk of geothermal development for direct use.

Each potentially viable geothermal direct use enterprise discussed in Chapter 2 – Geothermal Direct Use Enterprises, has a minimum temperature heat source requirement. Based on the minimum temperature requirements, it was determined that only existing wells with a recorded fluid temperature of 49 degrees C (120 degree F) or higher would be considered for geothermal direct use development. All but one of the water exploration / production wells were eliminated because of inadequate water temperatures. In addition, shallow geothermal exploration wells TH-1 and TH-2 were eliminated because they do not reach the water table. Shallow geothermal exploration well TH-4 was eliminated because of inadequate water temperature. Two of the three groundwater monitoring wells (MW-1 and MW-3) were eliminated because of inadequate water temperatures. All of the deep geothermal exploration / production wells were removed from consideration for a number of reasons. The KS series wells are used by PGV, HGP-A was plugged, Lani-1 and Lani-6 were plugged, TMP will be plugged, and Ashida was plugged.

All three of the scientific observation holes (SOH-1, SOH-2, and SOH-4) were eliminated because they were never intended or permitted for geothermal production. Only three existing shallow wells Malama Ki, MW-2, and TH-3 (GTW-3) passed the initial minimum temperature requirement screening.

Malama Ki has a relatively cold source of geothermally heated water with a maximum temperature of 56 degrees C (133 degrees F). The well site is remote and has no nearby utilities to support development. The closest potable water pipeline is located approximately 1-mile away, the closest electrical service is estimated to be approximately 1/2-mile away, and the closest paved road is located approximately 1/2-mile away. Individual wastewater systems would need to be installed if the area were to be developed. Malama Ki is located on a 190-acre parcel with TMK 1-3-007:031 and street address 13-769 Pohoiki Road. The parcel is zoned Conservation District and as such, commercial development might be limited without rezoning. The parcel is currently owned by State of Hawaii and used by the University of Hawaii at Manoa College of Tropical Agriculture and Human Resources (CTAHR) as an agriculture research center. It is unknown whether the shallow geothermal well Malama Ki is in fit condition to be developed and used for geothermal direct use.

Monitoring well MW-2 has slightly warmer water than Malama Ki with a maximum temperature of 67 degrees C (153 degrees F). The well site is near utilities to support development. The closest potable water pipeline is located approximately 1/10-mile away, the closest electrical service is estimated to be approximately 1/10-mile away, and the closest major paved road, Pohoiki Road is located approximately 1/4-mile away. Individual wastewater systems would need to be installed if the area were to be developed. MW-2 is located on an 86-acre parcel with TMK 1-4-001:002 and street address 14-3860 Kapoho Pahoa Road. The parcel is zoned Agricultural and would need to be used for agricultural purposes, or rezoned if it were to be used for non-agriculture commercial use. The Kapoho Land & Development Company, Ltd. and the Kapoho Land Partnership currently own the parcel. PGV leases the property for electricity generation using geothermal energy. Monitoring well MW-2 is currently used by PGV for monitoring purposes. It is unknown whether the shallow geothermal well MW-2 is in fit condition to be developed and used for geothermal direct use.

Geothermal exploration well TH-3 (GTW-3) has relatively hot water with a maximum temperature of 95 degrees C (203 degrees F). The well site has no utilities to support development. The closest potable water pipeline is located approximately 1-mile away, the closest electrical service is estimated to be approximately 1/2-mile away, and the closest paved road is located approximately 1/2-mile away. Individual wastewater systems would need to be installed if the area were to be developed. GTW-3 is located on a 14-acre parcel with TMK 1-4-018:011 and no street address. The parcel is zoned Agricultural and would need to be used for agricultural purposes, or rezoned if it were to be used for non-agriculture commercial use. The parcel is owned by private individuals and is currently unused. Shallow geothermal well TH-3 is used periodically by PGV for monitoring purposes. The well casing is reportedly in poor condition and it is questionable whether the geothermal well TH-3 is in fit condition to be developed and used for geothermal direct use.

The big drawback with all three wells, Malama Ki, MW-2, and TH-3, is that the hot water production capacity of each well is uncertain and suspected to be low. A dissertation entitled *The Hydrothermal System of the Lower East Rift Zone of Kilauea Volcano: Conceptual and Numerical Models of Energy and Solute Transport* by Dr. Stephen B. Gingerich attempted to accomplish several tasks including locating and quantifying shallow geothermal resources supplying hot water to Malama Ki, MW-2, and TH-3. Dr. Gingerich's research and modeling efforts suggested the following:

- The sources of heated water in shallow wells are geological fractures that allow geothermally heated water to rise to the top of the water table.
- All shallow wells with heated water have a stratified temperature profile where a relatively thin layer of hot water sits on cool water. See Figure 3-2 for temperature profiles of wells examined by Dr. Gingerich.
- Malama Ki is located approximately 730 meters (2,395 feet) down gradient of a fracture producing the equivalent of 0.061 kg/s/m (0.041 lb/s/ft or 0.29 gpm/ft) of 100 degree C (212 degree F) water. See Figure 3-3 for measured and modeled temperature profiles of Malama Ki.
- MW-2 is located approximately 105 meters (344 feet) down gradient of a fracture producing the equivalent of 0.02545 kg/s/m (0.017 lb/s/ft or 0.12 gpm/ft) of 100 degree C (212 degree F) water. See Figure 3-4 for measured and modeled temperature profiles of MW-2.
- TH-3 is located approximately 170 meters (558 feet) down gradient of a fracture producing the equivalent of 0.126 kg/s/m (0.085 lb/s/ft or 0.61 gpm/ft) of 100 degree C (212 degree F) water. See Figure 3-5 for measured and modeled temperature profiles of TH-3.

The accuracy of the modeling results and subsequent conclusions are unknown due to limited available computer resources, limited available data, and modeling limitations. The model created for the dissertation was a 2-dimensional model attempting to describe a 3-dimensional system. It is unknown if the source of shallow geothermal water are indeed fractures, what the length of the fractures are, what the expected life of the fractures are, what the temperature of the heated water from the fractures is, and what quantity of hot water is being supplied by the fractures. Assuming that all of the conclusions presented in the dissertation are accurate, it is unclear how much hot water can be extracted from a well located directly above a fracture. Presumably any shallow geothermal well will be susceptible to a phenomenon called upconing if a pump is used to extract heated water. Upconing is a term used to describe an event where layers of different fluids such as fresh water and salt water, or heated water and cold water end up mixing because the rate of extraction is too great and causes the denser water to be sucked up by

GEOTHERMAL HEAT RESOURCES
FIGURE 3-2: TEMPERATURE PROFILES OF EXISTING WELLS

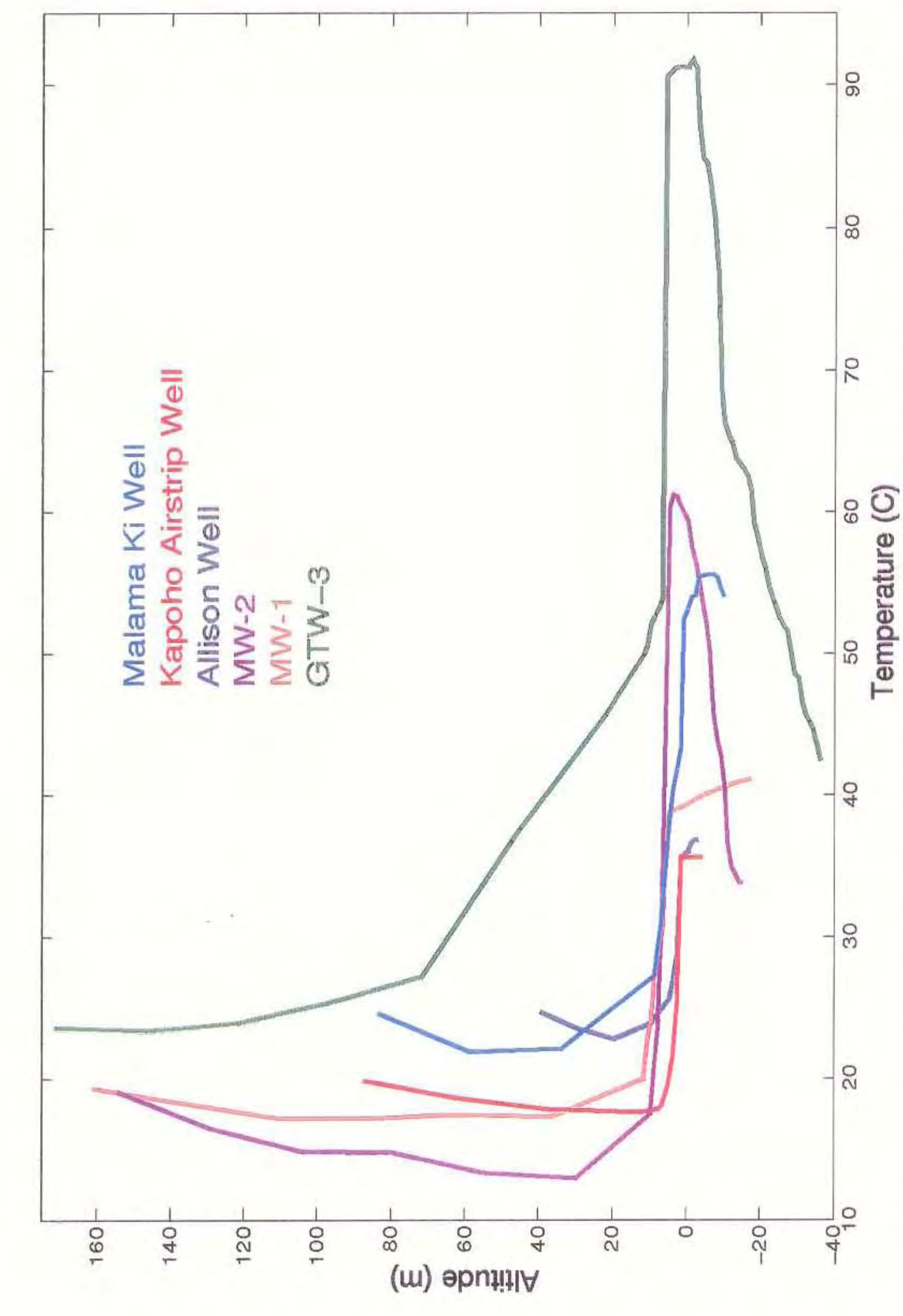


Figure 4.14 Temperature profiles in East Rift Zone shallow wells, June 1, 1994.

Figure 4-14 taken from a dissertation written by Dr. Stephen Gingerich entitled "The Hydrothermal System of the Lower East Rift Zone of Kilauea Volcano: Conceptual and Numerical Models of Energy and Solute Transport"

GEOTHERMAL HEAT RESOURCES
FIGURE 3-3: TEMPERATURE PROFILES OF MALAMA KI

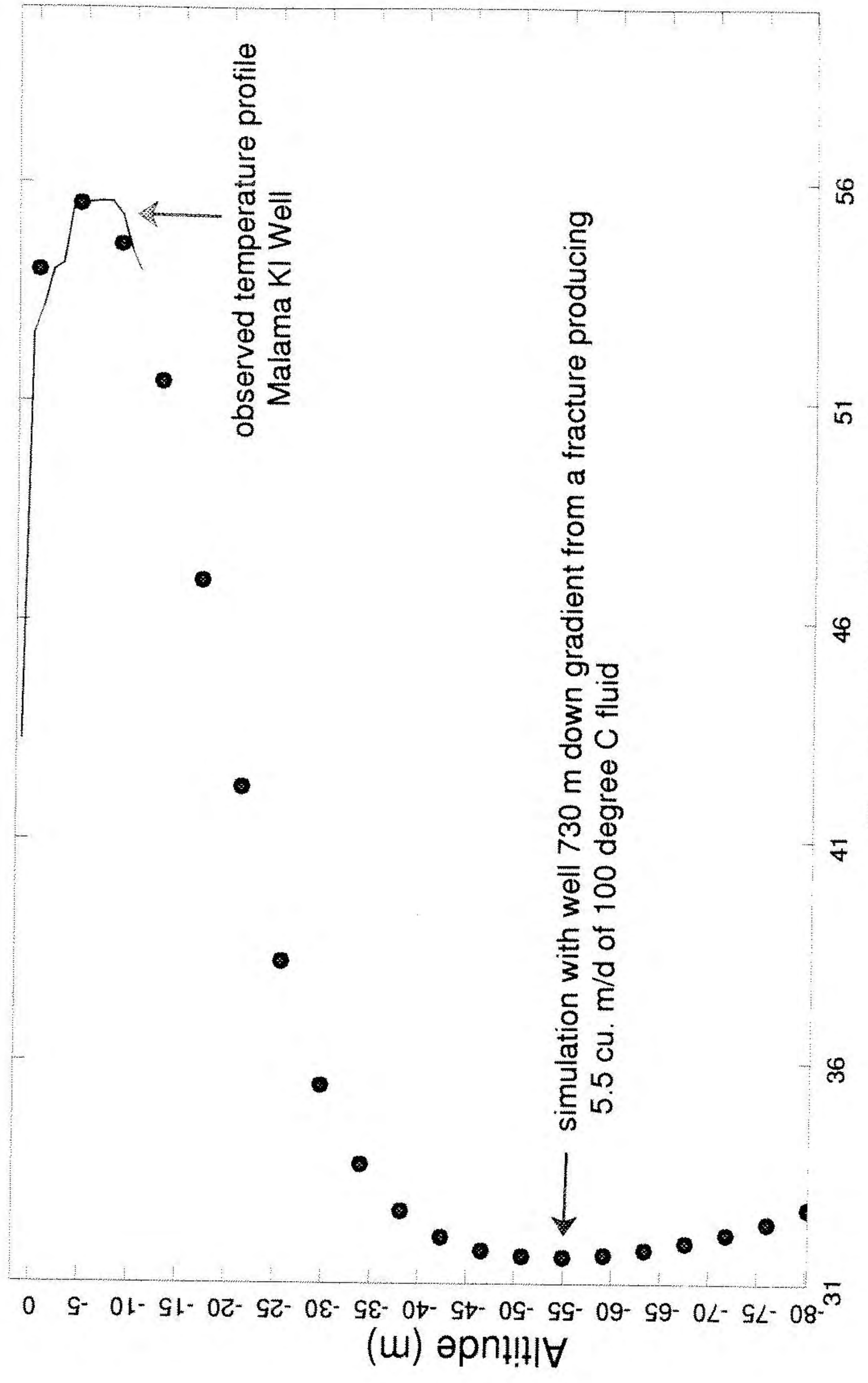


Figure 6.6 Observed and simulated temperature profiles, Malama Ki Well.

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Figure 6-6 taken from a dissertation written by Dr. Stephen Gingerich entitled "The Hydrothermal System of the Lower East Rift Zone of Kilauea Volcano: Conceptual and Numerical Models of Energy and Solute Transport"

GEOTHERMAL HEAT RESOURCES
FIGURE 3-4: TEMPERATURE PROFILES OF MW-2

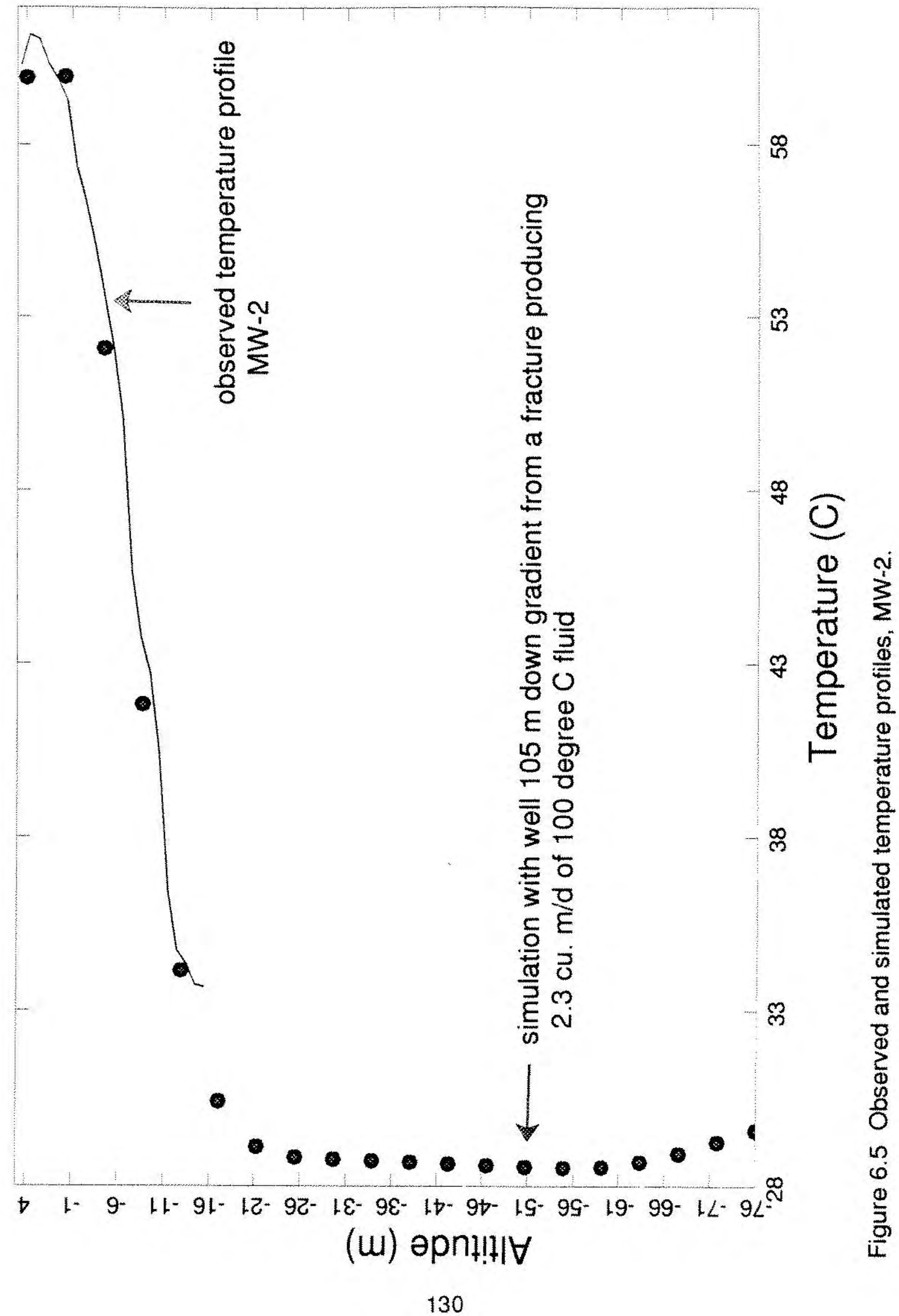

Figure 6-5 taken from a dissertation written by Dr. Stephen Gingerich entitled "The Hydrothermal System of the Lower East Rift Zone of Kilauea Volcano: Conceptual and Numerical Models of Energy and Solute Transport"

GEOTHERMAL HEAT RESOURCES
FIGURE 3-5: TEMPERATURE PROFILES OF TH-3

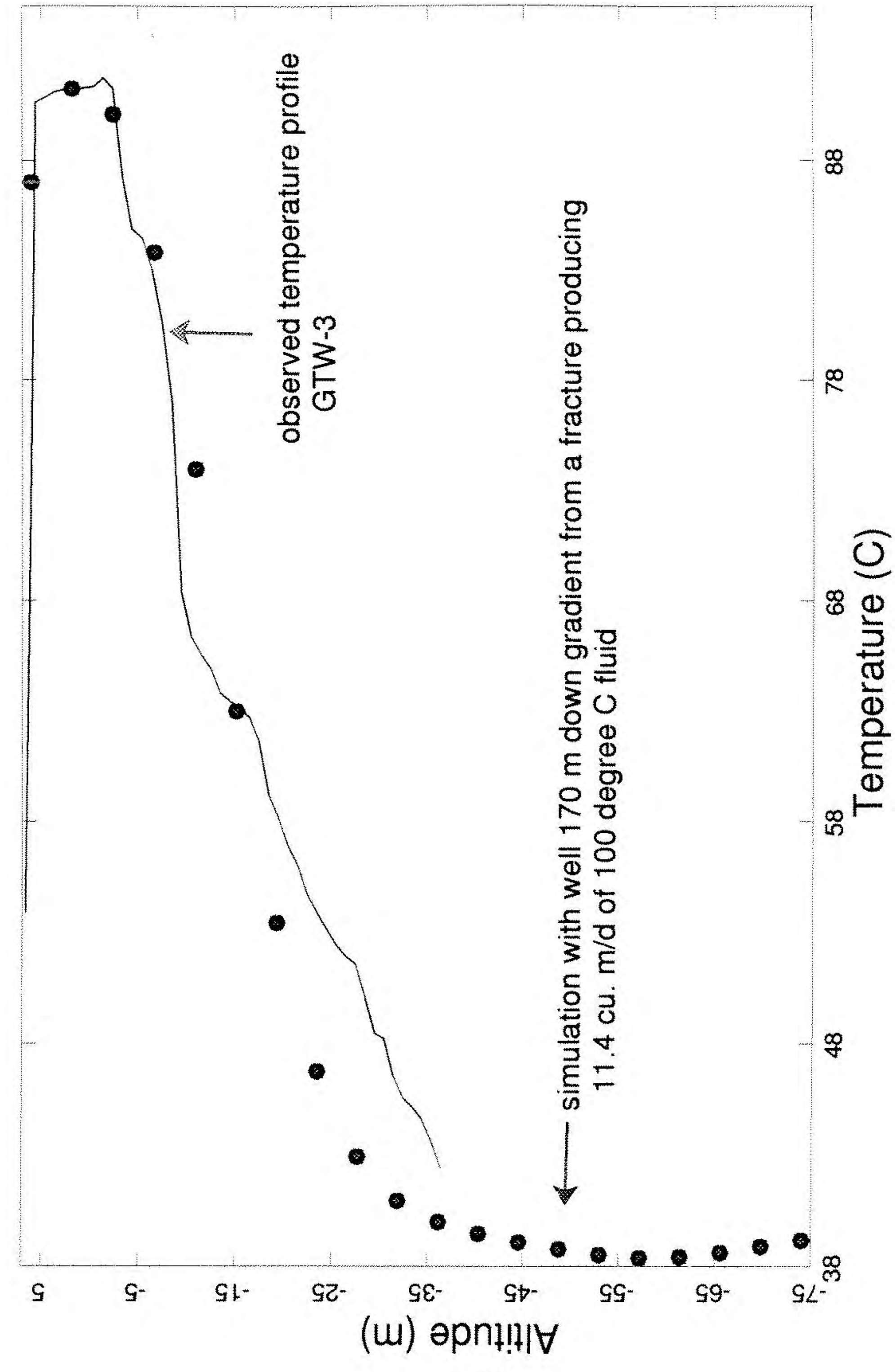

Figure 6.4 Observed and simulated temperature profiles, GTW-3.

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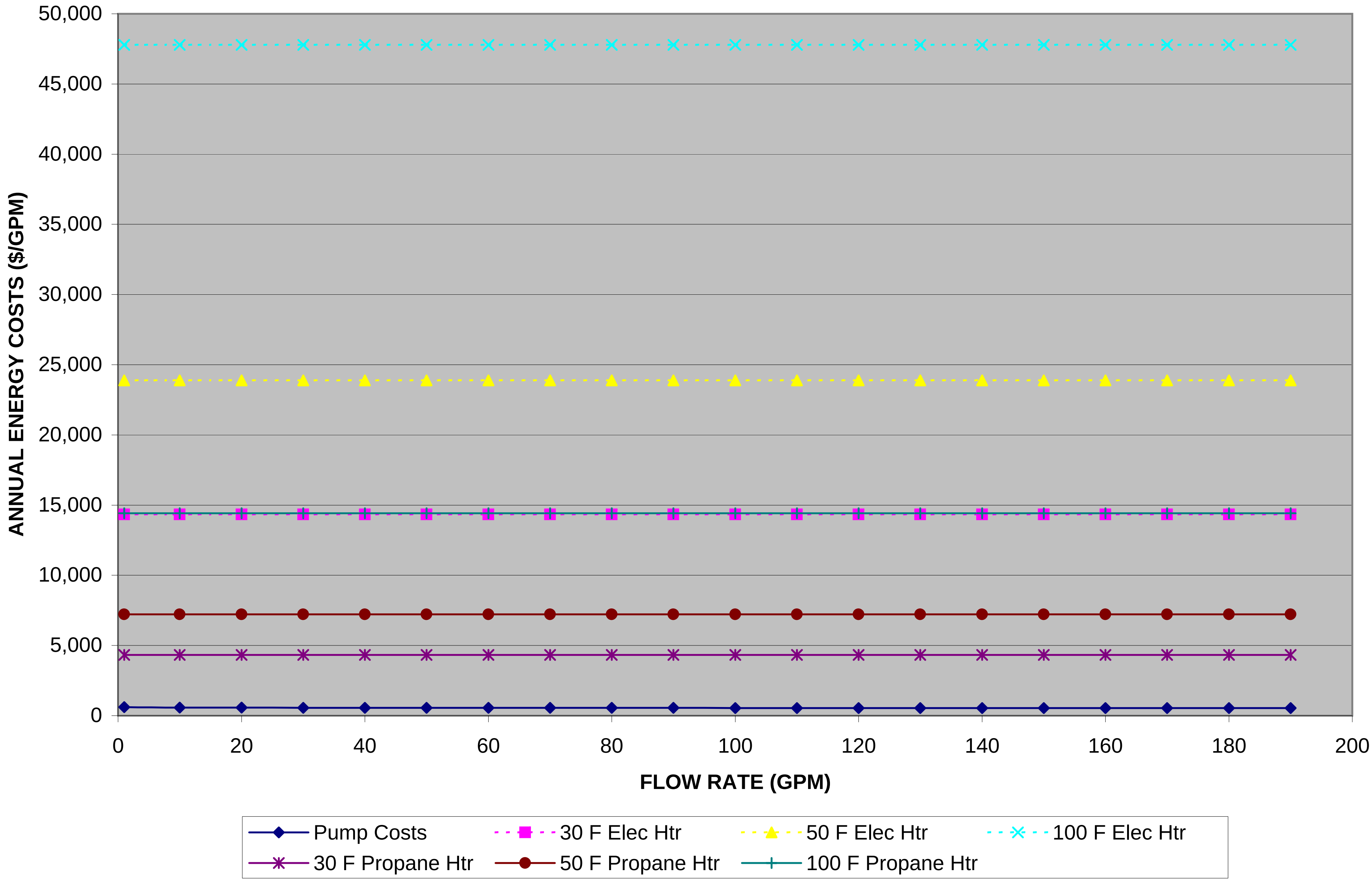
Figure 6-4 taken from a dissertation written by Dr. Stephen Gingerich entitled "The Hydrothermal System of the Lower East Rift Zone of Kilauea Volcano: Conceptual and Numerical Models of Energy and Solute Transport"

the pump. The pumping rate will need to be limited to avoid causing hot geothermal water and cold ground water to mix.

A quick analysis was done to determine if extracting heat or heated water from an existing shallow well could be feasible. One alternative to extracting geothermally heated hot water is to use an electric or a propane fired water heater to produce hot water. A cost analysis was prepared to compare approximate costs to pump geothermally heated water to the surface, heat water using electricity, and heat water using propane. Annual costs were based on a flow rate of one gpm of hot water supplied 24 hours a day. See Chart 3-1, Table 3-2, and Table 3-3 for assumptions, sample calculations, and results. It would cost approximately $47,800 in electricity or $14,400 in propane annually, at 2006 prices, to heat 1 gpm of water from 38 to 93 degrees C (100 to 200 degrees F). In other words, each gpm of 93 degree C (200 degree F) geothermally heated water is worth approximately $14,400 minus $600 pumping costs annually. Of the three existing wells analyzed by Dr. Gingerich, TH-3 is estimated to have the largest hot water source potential at 0.126 $kg/s/m_{fracture}$ (0.61 $gpm/foot_{fracture}$) of 93 degree C (200 degree F) water. Assuming that all of the heat from a fracture section three feet long could be successfully extracted by a pump or downhole heat exchanger, approximately 0.378 kg/s (1.83 gpm) of 93 degree C (200 degree F) water could be supplied. This is the equivalent of $25,254 worth of propane energy using a pump, or $20,736 worth of propane energy using an 80% efficient downhole heat exchanger. Based on a rough cost analysis, an arbitrarily selected acceptable arithmetic rate of return of 10%, and ignoring many factors, a $25,000 energy source would justify an investment of $250,000.

None of the three existing shallow geothermal wells were retained for further consideration based on the following:

GEOTHERMAL HEAT RESOURCES
CHART 3-1: SHALLOW WELL PUMP VS. HEATING COST ANALYSIS



GEOTHERMAL HEAT RESOURCES
TABLE 3-2: SHALLOW WELL PUMPING ANALYSIS
(Sheet 1 of 2)

Flowrate (gpm)	Head[1] (ft)	Pump[2] (bhp)	Motor (eff.)[4]	Motor (hp)	Motor (kw)	Electricity Costs[3] ($ per hr)	Electricity Costs[3] ($ per day)	Electricity Costs[3] ($ per yr)	Electricity Costs[3] ($/yr/gpm)
1	700	0.22	82.5	0.27	0.20	0.07	1.68	613	613
10	700	2.21	87.5	2.53	1.89	0.66	15.88	5,795	579
20	700	4.42	87.5	5.05	3.77	1.32	31.67	11,559	578
30	700	6.64	90.2	7.36	5.49	1.92	46.12	16,832	561
40	700	8.85	90.2	9.81	7.32	2.56	61.49	22,443	561
50	700	11.06	91.0	12.15	9.06	3.17	76.10	27,778	556
60	700	13.27	91.0	14.58	10.87	3.80	91.31	33,327	555
70	700	15.48	91.7	16.88	12.59	4.41	105.76	38,601	551
80	700	17.69	91.7	19.29	14.38	5.03	120.79	44,089	551
90	700	19.91	91.7	21.71	16.19	5.67	136.00	49,639	552
100	700	22.12	92.4	23.94	17.85	6.25	149.94	54,728	547
110	700	24.33	92.4	26.33	19.63	6.87	164.89	60,186	547
120	700	26.54	92.4	28.72	21.42	7.50	179.93	65,674	547
130	700	28.75	92.4	31.11	23.20	8.12	194.88	71,131	547
140	700	30.97	93.0	33.30	24.83	8.69	208.57	76,129	544
150	700	33.18	93.0	35.68	26.61	9.31	223.52	81,586	544
160	700	35.39	93.0	38.05	28.37	9.93	238.31	86,982	544
170	700	37.60	93.0	40.43	30.15	10.55	253.26	92,440	544
180	700	39.81	93.0	42.81	31.92	11.17	268.13	97,867	544
190	700	42.02	93.6	44.89	33.47	11.71	281.15	102,619	540

Electricity Cost per kwh = $0.35
Pump Efficiency (%) = 80

[1] Head only includes elevation head. Pump is assumed to be at ground elevation; ground elevation is assumed to be approximately 700 feet msl; water is assumed to be located at 0 feet msl.
[2] Pump efficiency is assumed to be 80%.
[3] Local electricity costs per kwh is assumed to be $0.35. Pump is assumed to operate 24 hours a day.
[4] Motor efficiency is based on NEMA Premium efficiency motors.

Sample Calculations

Calculate required pump break horsepower:

Pump (bhp) = h Q(SG)/(3956η)

Where: h = head (feet)
Q = flow rate (gpm)
SG = specific gravity (1.0 for water)
η_p = pump efficiency

Pump (bhp) = (700 feet)*(1 gpm)*(1.0)/(3956*0.80) = 0.22 hp

Calculate required motor horsepower:

Motor (hp) = [Pump (bhp)]/η_m

Where: η_m = motor efficiency

Motor (hp) = (0.22 hp)/(0.825) = 0.27 hp

GEOTHERMAL HEAT RESOURCES
TABLE 3-2: SHALLOW WELL PUMPING ANALYSIS
(Sheet 2 of 2)

Calculate motor electricity consumption:

Motor (kw) = [Motor (hp)]*(0.7457 kw/hp) = (0.27 hp)*(0.7457 kw/hp) = 0.20 kw

Calculate annual electricity energy costs:

Annual Energy Costs = [Motor (kw)]*[Electricity Rate ($/kwh)]*(24 hr/day)*(365 days/year)

Annual Energy Costs = (0.20 kw)*($0.35/kwh)*(24 hr/day)*(365 days/year) = $613 per year

GEOTHERMAL HEAT RESOURCES
TABLE 3-3: WATER HEATING ANALYSIS
(SHALLOW GEOTHERMAL WELL EQUIVALENT TEMPERATURE WATER)
(Sheet 1 of 2)

Flowrate	Temperature Rise[1]			Req'd Heat Input (Btu/hr)			Annual Elect. Costs ($/gpm)[2, 3]			Annual Gas Costs ($/gpm)[4, 5]		
(gpm)	(degrees F)			(30°F)	(50°F)	(100°F)	(30°F)	(50°F)	(100°F)	(30°F)	(50°F)	(100°F)
1	30	50	100	14,994	24,990	49,980	14,334	23,889	47,778	4,328	7,213	14,427
10	30	50	100	149,940	249,900	499,800	14,334	23,889	47,778	4,328	7,213	14,427
20	30	50	100	299,880	499,800	999,600	14,334	23,889	47,778	4,328	7,213	14,427
30	30	50	100	449,820	749,700	1,499,400	14,334	23,889	47,778	4,328	7,213	14,427
40	30	50	100	599,760	999,600	1,999,200	14,334	23,889	47,778	4,328	7,213	14,427
50	30	50	100	749,700	1,249,500	2,499,000	14,334	23,889	47,778	4,328	7,213	14,427
60	30	50	100	899,640	1,499,400	2,998,800	14,334	23,889	47,778	4,328	7,213	14,427
70	30	50	100	1,049,580	1,749,300	3,498,600	14,334	23,889	47,778	4,328	7,213	14,427
80	30	50	100	1,199,520	1,999,200	3,998,400	14,334	23,889	47,778	4,328	7,213	14,427
90	30	50	100	1,349,460	2,249,100	4,498,200	14,334	23,889	47,778	4,328	7,213	14,427
100	30	50	100	1,499,400	2,499,000	4,998,000	14,334	23,889	47,778	4,328	7,213	14,427
110	30	50	100	1,649,340	2,748,900	5,497,800	14,334	23,889	47,778	4,328	7,213	14,427
120	30	50	100	1,799,280	2,998,800	5,997,600	14,334	23,889	47,778	4,328	7,213	14,427
130	30	50	100	1,949,220	3,248,700	6,497,400	14,334	23,889	47,778	4,328	7,213	14,427
140	30	50	100	2,099,160	3,498,600	6,997,200	14,334	23,889	47,778	4,328	7,213	14,427
150	30	50	100	2,249,100	3,748,500	7,497,000	14,334	23,889	47,778	4,328	7,213	14,427
160	30	50	100	2,399,040	3,998,400	7,996,800	14,334	23,889	47,778	4,328	7,213	14,427
170	30	50	100	2,548,980	4,248,300	8,496,600	14,334	23,889	47,778	4,328	7,213	14,427
180	30	50	100	2,698,920	4,498,200	8,996,400	14,334	23,889	47,778	4,328	7,213	14,427
190	30	50	100	2,848,860	4,748,100	9,496,200	14,334	23,889	47,778	4,328	7,213	14,427

Electricity Cost per kwh =	$0.35
Propane Commercial Cost per gallon =	$1.75
Electric Water Heater Efficiency (%) =	0.94
Gas Water Heater Efficiency (%) =	0.63

[1] Assumed that the water temperature starts off at 100 degrees F to simulate return water temperatures from geothermal direct use applications. Used 30 degree F temperature rise to simulate Malama Ki (133 degree F) water. Used 50 degree F temperature rise to simulate MW-2 (153 degree F) water. Used 100 degree F temperature rise to simulate TH-3 (GTW-3, 203 degree F) water.
[2] Used 3,412 Btu/hr as the equivalent of 1 kw.
[3] Local electricity costs per kwh is assumed to be $0.35. Heater is assumed to operate 24 hours a day.
[4] Used 84,300 Btu as the equivalent of 1 gallon of propane.
[5] Local propane commercial costs per gallon is assumed to be $1.75. Heater is assumed to operate 24 hours a day.

Sample Calculations
Calculate water heating requirements:

q = mc(deltaT)

Where:
q = required heat input (btu/hr)
m = mass flow rate (lbs/hr)
c = specific heat of water [btu/(lbm*deg F)], 1.0 for water between 100 and 200 degrees F
delta T = temperature rise (degrees F)

q = [(1 gpm)*(8.33 lbm/gallon)*(60 min/hr)]*(1.0 btu/lbm/degF)*(30 degrees F) = 14,994 btu/hr

Calculate annual electricity energy costs per gpm:

GEOTHERMAL HEAT RESOURCES
TABLE 3-3: WATER HEATING ANALYSIS
(SHALLOW GEOTHERMAL WELL EQUIVALENT TEMPERATURE WATER)
(Sheet 2 of 2)

Annual Electricity Costs = (q)/(3412 btu/hr/kw)/η_e*[Electricity Rate ($/kwh)]*(24 hr/day)*(365 days/year)/Q

Where: q = required heat input (btu/hr)
η_e = electric water heater efficiency
Q = flow rate (gpm)

Annual Electricity Costs = (14994 btu/hr)/(3412 btu/hr/kw)/(0.94)*($0.35 /kwh)*(24 hr/day)*(365 days/year)/(1 gpm)
Annual Electricity Costs = $14,334 /gpm/year

Calculate annual propane energy costs per gpm:
Annual Propane Costs = (q)/(84300 btu/gallon of propane)/η_p*[Propane Cost ($/gallon)]*(24 hr/day)*(365 days/year)/Q

Where: q = required heat input (btu/hr)
η_p = propane water heater efficiency
Q = flow rate (gpm)

Annual Propane Costs = (14994 btu/hr)/(84300 btu/gallon of propane)/(0.63)*($1.75 /gallon)*(24 hr/day)*(365 days/year)/(1 gpm)
Annual Propane Costs = $4,328 /gpm/year

Malama Ki:

- Malama Ki is located on conservation district zoned land and development may be limited without rezoning. Depending on which conservation district subzone it is in, uses such as horticulture, floriculture, forestry, animal husbandry, aquaculture, mining, landscaping, farming, grazing and orchards could be allowed.
- The geothermally heated well water is relatively cold at a maximum-recorded temperature of 56 degrees C (133 degrees F). It would be difficult to extract sufficient quantities of heated water from the well for many direct use enterprises.
- Malama Ki is located approximately 1-mile from the nearest potable water source, 1/2-mile from the nearest electricity power source, 1/2-mile from the nearest paved road. A significant investment would be required to extend existing infrastructure necessary for development.
- With an equivalent estimated hot water production rate of 0.061 $kg/s/m_{fracture}$ (0.29 $gpm/ft_{fracture}$) of 93 degree C (200 degree F) water, a maximum of $4,000 of equivalent propane heated hot water per foot of fracture could be extracted from the well. Arbitrarily assuming that all of the hot water from a fracture section three feet long could be successfully extracted, only $12,000 worth of equivalent propane heated hot water could be produced. An energy savings of $12,000 would not justify the infrastructure/capital necessary for geothermal direct use development. Furthermore, the small quantity of hot water would significantly hamper the growth of geothermal direct use enterprises.

MW-2:

- MW-2 is located approximately 1/10-mile from the nearest potable water source, 1/10-mile from the nearest electricity power source, 1/4 mile from the nearest main paved road. A significant investment would be required to extend existing infrastructure necessary for geothermal direct use development.
- With an equivalent estimated hot water production rate of 0.02545 $kg/s/m_{fracture}$ (0.12 $gpm/ft_{fracture}$) of 93 degree C (200 degree F) water, a maximum of $1,656 of equivalent propane heated hot water per foot of fracture could be extracted from the well. Arbitrarily assuming that all of the hot water from a fracture section three feet long could be successfully extracted; only $4,968 worth of equivalent propane heated hot water could be produced. An energy savings of $4,968 would not justify the infrastructure/capital necessary for geothermal direct use development. Furthermore, the small quantity of hot water would significantly hamper the growth of geothermal direct use enterprises.

TH-3 (GTW-3):

- TH-3 is located approximately 1-mile from the nearest potable water source, 1/2-mile from the nearest electricity power source, 1/2-mile from the nearest paved road. A significant investment would be required to extend existing infrastructure necessary for geothermal direct use development.
- With an equivalent estimated hot water production rate of 0.126 kg/s/$m_{fracture}$ (0.61 gpm/$ft_{fracture}$) of 93 degree C (200 degree F) water, a maximum of $8,418 of equivalent propane heated hot water per foot of fracture could be extracted from the well. Arbitrarily assuming that all of the hot water from a fracture section three feet long could be successfully extracted; only $25,254 worth of equivalent propane heated hot water could be produced. An energy savings of $25,254 would not justify the infrastructure/capital necessary for geothermal direct use development. Furthermore, the small quantity of hot water would significantly hamper the growth of geothermal direct use enterprises.

3.4.2 Geothermal Resources – Drilling New Wells

Drilling new wells is a very expensive venture and has a success rate approaching 80% at best when expensive studies are undertaken. Shallow geothermal wells, 8-inches in diameter, and 700 feet in depth are estimated to cost approximately $400,000 each in the Kapoho / Pohoiki area based on discussions with local drilling companies Water Resources International, Inc., Beylik Drilling, and Fred Page Drilling. Deep geothermal wells are estimated to cost $6-8 million each (Kaleikini 2006).

Drilling shallow geothermal wells may be an ineffective means of accessing shallow geothermal fluids in the Kapoho / Pohoiki area based on research by Dr. Gingerich. His research suggests that shallow geothermally heated water in the Kapoho / Pohoiki area exists as a thin layer of heated water floating on cold water. The thin layer of hot water would make it very difficult to extract sufficient quantities of heated water with the use of pumps or downhole heat exchangers. Drilling shallow geothermal wells was removed from consideration for geothermal direct use because of the anticipated low heat production rate capacity of shallow geothermal wells.

Drilling deep geothermal wells is very expensive and 2 to 3 wells would need to be drilled for geothermal direct use. One well would be designated for geothermal production, one well would be designated for geothermal fluid injection, and one well would be designated for backup geothermal production. Estimated drilling costs excluding permits, studies, infrastructure upgrades, and consultant fees start at $18-24 million. Drilling costs could escalate if a geothermal production resource is not found. Drilling deep geothermal wells were removed from consideration for geothermal direct use because of the prohibitively high drilling costs.

3.4.3 Geothermal Resources – Extracting Heat From Hot Dry Rock

Extracting heat from hot dry rock involves drilling two holes, fracturing the rock, and circulating a fluid to extract the heat. This method is currently experimental, and will be most applicable to locations which, unlike Hawaii, have insufficient fluid in the geothermal reservoir to transport heat. It was removed from consideration for geothermal direct use.

3.4.4 Geothermal Resources – Acquiring Waste Heat From PGV

PGV produces 25-30 MW of electricity and has plans to increase electricity production. They inject 4,000 gpm of geothermal fluid at a temperature of approximately 167 degrees C (333 degrees F). Planned power plant modifications are expected to reduce the temperature of injected geothermal fluid to approximately 75 degrees C (168 degrees F).

PGV has expressed no intention of charging for waste heat utilized for geothermal direct use provided the following conditions are met:

- Heat provided for geothermal direct use must be waste heat that cannot be used to produce electricity.
- Geothermal direct use of waste heat cannot adversely affect PGV operations.
- Geothermal fluids cannot be removed from PGV's leased property.
- PGV will not stray from its core business of generating electricity. Waste heat will be provided at PGV's convenience.
- PGV will require a Master Work Agreement with the entity receiving waste heat. Agreement has several requirements including liability insurance.
- PGV will not pay for any necessary improvements including pipe connections, heat exchanger, pumps, etc.

PGV leases the property where it extracts geothermal heat as well as the surrounding properties. The properties have a combined land area of approximately 815 acres. The parcel where PGV operations are located and the immediate surrounding parcel are designated TMK 1-4-001:002 and 019. They are both zoned Agricultural and have a street address of 14-3860 Kapoho Pahoa Road. The Kapoho Land & Development Company, Ltd. and the Kapoho Land Partnership own all 815 acres that PGV leases. The Kapoho Land & Development Company, Ltd. and the Kapoho Land Partnership support geothermal direct use, but have expressed that they may impose conditions additional to PGV's on geothermal direct use development.

Based on a combination of geothermal fluid chemistry in the Kapoho / Pohoiki area, planned PGV power plant modifications, and restrictions imposed by PGV, acquiring waste heat from PGV was determined to be unlikely. Geothermal fluid obtained by PGV is high in silica content and any reduction in fluid temperature increases the chances of scaling. It is feared that extracting heat from the spent geothermal fluid for direct use would further reduce the temperature and could result in scaling damage to PGV's facilities including piping, heat exchangers, equipment, and injection wells. Although it is not 100% certain that the planned power plant modifications will be implemented, recent developments indicate that they are close to becoming a reality.

3.4.5 Geothermal Resources – Acquiring Waste Heat From Future Application

"Waste heat" may be available from a future application of high temperature geothermal heat. Potential future applications of high temperature geothermal heat including a manufacturing facility that requires steam, an ethanol production plant, or power plant may be able afford the high costs of geothermal energy development, including studies and drilling.

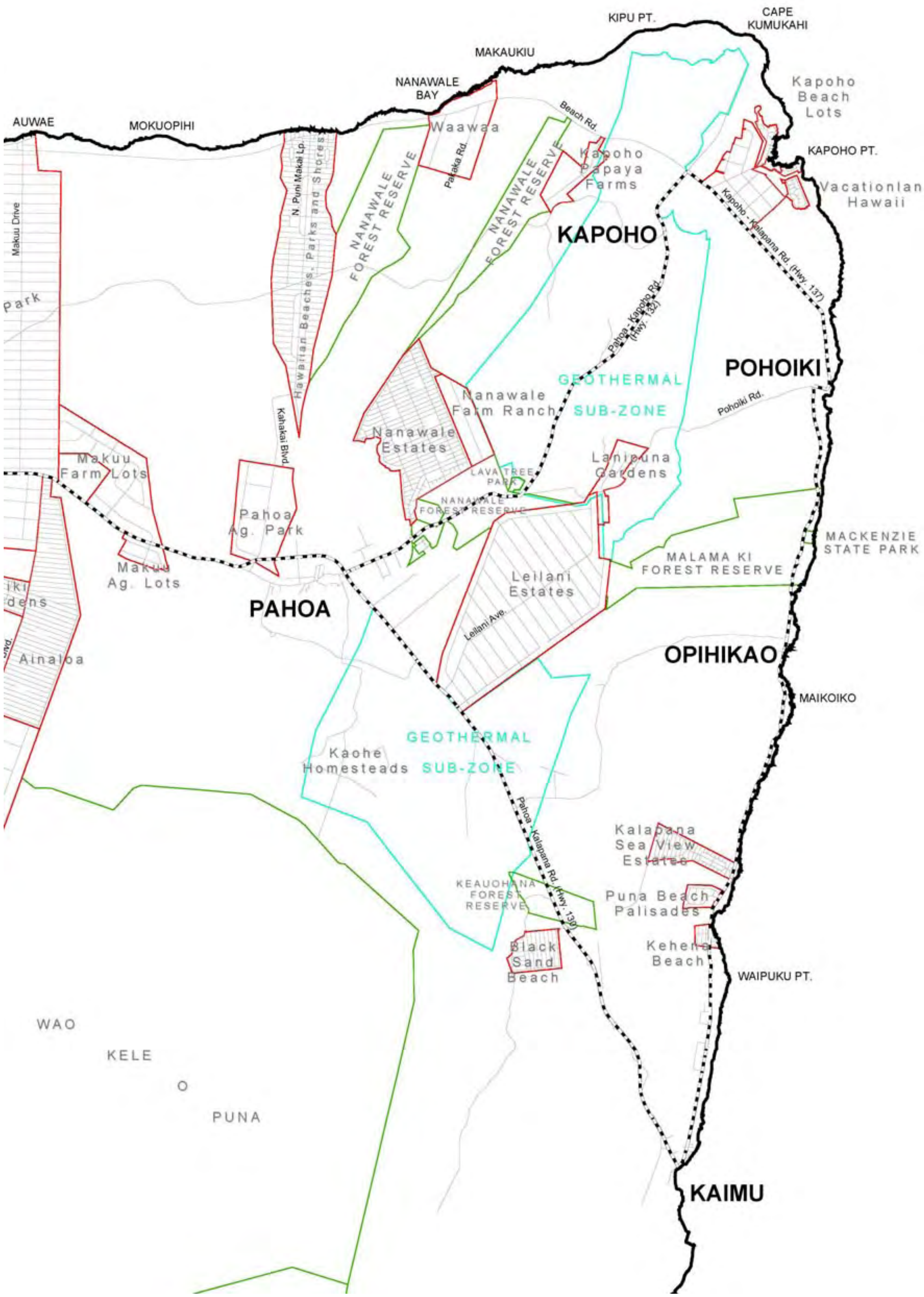
The location of such a future facility would depend on a number of factors including geothermal resource subzones, predicted geothermal fracture locations, zoning of land, proximity to roads and utilities, and successful negotiations with existing land owners.

Potential facilities would be required to be located within geothermal resource subzones as determined by the Board of Land and Natural Resources (BLNR). See Figure 3-6 for the location of geothermal resource subzones in the Kapoho / Pohoiki area. Hawaii Revised Statutes (HRS) 205 requires that all "geothermal development activities" must occur in geothermal resource subzones. HRS Section 205-5.1 defines "geothermal development activities" as "the exploration, development, or production of electrical energy from geothermal resources and direct use applications of geothermal resources".

Potential facilities would need to be located over geothermal resources with the ability to produce sufficient, sustainable, quantities of heat. Extensive studies and testing would be necessary to maximize the chance of discovering such a resource.

Potential facilities would need to be located on land zoned for the appropriate use or they must apply for the necessary permits / zone changes. Facilities

GEOTHERMAL HEAT RESOURCES
FIGURE 3-6: GEOTHERMAL RESOURCE SUBZONES



This map is an excerpt from a map prepared by the County of Hawaii for the Puna Community - County Development Plan. The Wao Kele O Puna geothermal subzone is not shown on the map.

proposed to be located on conservation district use zoned land may need to apply for a conservation district use permit from BLNR. Facilities proposed to be located on lands zoned for other uses would need to apply for a zone change.

Potential facilities would need to be located within close proximity to existing roadways and utilities to reduce development costs. Roadways are the most costly of the necessary infrastructures and could be a deciding factor of potential locations. Water and electricity are also necessary but are typically located adjacent to major roadways. The County water system does not extend very far into the geothermal resource subzones in the Kapoho / Pohoiki area. See Figure 3-7 for a map of the County water system in the area.

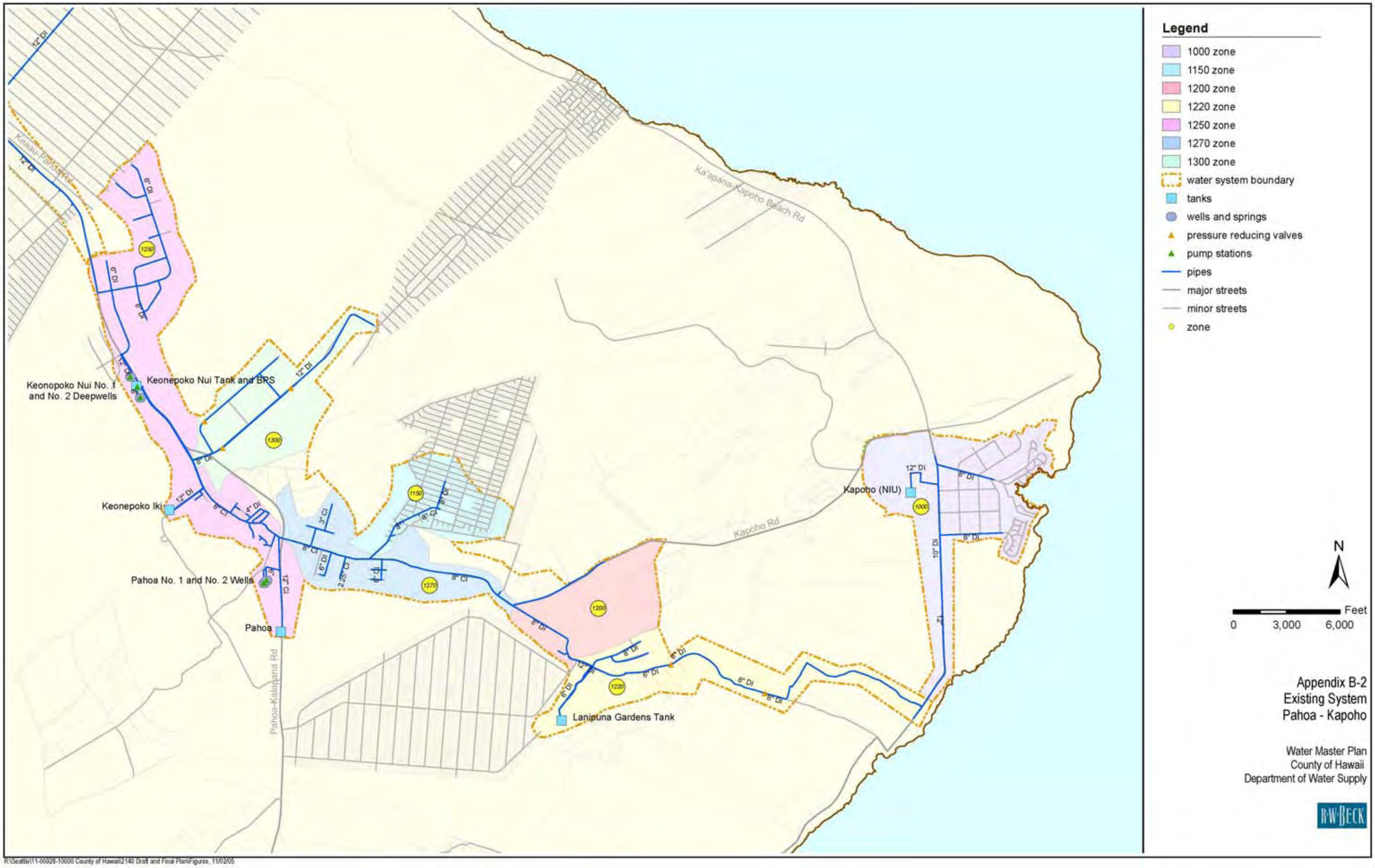
Finally, entrepreneurs of potential facilities would need to successfully negotiate favorable lease or purchasing terms of property.

Based on the minimum above criteria, potential facilities would likely be located along the Pahoa – Kalapana Road (Highway 130) or the Pahoa – Kapoho Road (Highway 132).

3.5 SUMMARY OF GEOTHERMAL HEAT RESOURCES

Utilizing existing wells, drilling new geothermal wells (shallow and deep), and extracting heat from hot dry rock were removed from consideration as a means to access geothermal resources in the Kapoho / Pohoiki area. Reasons for removing them from consideration include insufficient fluid temperatures, insufficient quantity of heated fluids, high costs of drilling, and inappropriate means of accessing the Puna geothermal resource. Acquiring waste heat from PGV is a highly unlikely option because of planned power plant modifications that will reduce the amount of available waste heat and increase the chance of encountering scaling problems. Acquiring waste heat

GEOTHERMAL HEAT RESOURCES
FIGURE 3-7: KAPOHO / POHOIKI COUNTY WATER SYSTEM



from a future application of geothermal heat was the only potentially viable source of heat that was identified.

The remainder of this feasibility study will be based on the premise that affordable access to geothermal heat for direct use will be available, whether it is from PGV or from a future application.

CHAPTER 4- STATE AND COUNTY REGULATORY IMPROVEMENTS TO ENCOURAGE THE DIRECT USE OF GEOTHERMAL HEAT

4.1 INTRODUCTION

State and County statutes, rules and regulations were not originally intended to either encourage or discourage direct use of geothermal resources because the initial support for and opposition to geothermal exploration and development focused on electricity generation. As a result, the regulatory and royalty structure was enacted to primarily deal with large commercial electrical operations.

The most potentially important statutory issue relating to direct use of geothermal is the royalty imposed by State law, paid to the State, and allocated in part to the County of Hawaii and the Office of Hawaiian Affairs. (A listing of State and County statutes and rules and regulations is attached as Appendix C.) A review of legislative history reveals that the Legislature intended that royalties could be waived to encourage the production and use of geothermal resources, even for non-electric purposes. However, it is less certain whether the portion of royalties allocated to the County can be used for purposes other than the mitigation of "negative impacts" of geothermal development.

This chapter deals with the present State and County statutory and regulatory structure. It does not include a review of potential or outstanding issues relating to State and County statutes, rules and regulations relating to the ownership of the geothermal resource.

4.2 LEGAL AUTHORITY FOR STATE ROYALTY

State law requires the Board of Land and Natural Resources to fix royalties to the State for "utilization of geothermal resources." §182-18, Hawaii Revised Statutes. The royalty is imposed on the mining lessee.

That provision, which became law in 1985 with the passage of Senate Bill No. 153 (Act 138, Session Laws of Hawaii, 1985), was intended to create a means to encourage the development of geothermal resources. By enacting a separate section of the law relating to geothermal royalties, the Legislature created a way to establish a unique royalty waiver provision without affecting other State leases. Specifically, the “waiver clause” of this section states:

> With respect to all geothermal mining leases previously issued or to be issued, where the board determines that it is necessary to <u>encourage the initial or continued production</u> of geothermal resources, the board shall have the authority to waive royalty payments to the State for any fixed period of time up to but not exceeding eight years. (Underlining added.)

Senate Standing Committee Report No. 301 by the Committee on Energy on Senate Bill No. 153 states the Legislature’s intent that:

> Major geothermal programs were initiated in Hawaii in the late seventies and early eighties when oil price projections made geothermal appear economically attractive. Since more than ninety percent of Hawaii's energy comes from imported oil, geothermal is a most promising alternate energy resource, the development of which is crucial to the economy of the State and to the achievement of the State Plan goal of energy self-sufficiency…Your Committee further finds that this bill will promote public interest by <u>encouraging exploration and development</u> as well as the continued production of geothermal resources which would not otherwise have been undertaken because of prohibitive financial costs. (Underlining added.)

The Board rule which implements this mandate sets the royalty rate of geothermal production at not less than ten percent nor more than twenty percent of the gross amount or value of the geothermal resources produced under the lease as measured at the wellhead and sold or utilized by the lessee. §13-183-31 (a), Title 13, Hawaii Administrative Rules. Therefore, if a direct user either produces the resource itself or purchases it from a producer, the royalty would apply (in the case of heat sold to the direct user, the producer would likely include the royalty as part of the charge.)

Certain "non sales" situations are covered by the Board rule, i.e., a producer producing geothermal resources using or furnishing the geothermal resource to a plant owned or controlled by the lessee. In such a case, a formula is contained in the rule to compute the amount owed to the State. §13-183-31 (b), Title 13, Hawaii Administrative Rules.

Although the initial focus of State regulation and royalties was on the electricity production potential of geothermal resources, the Legislature in 1990 acted affirmatively to encourage other uses. Act 207, Session Laws of Hawaii, 1990, amended the definition of "geothermal resources", contained in §182-1, Hawaii Revised Statutes, by inserting the following exclusion:

> Any water, mineral in solution, or other product obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, having a temperature of 150 degrees Fahrenheit or less, and not used for electrical power generation.

The effect of the exclusion was to exempt this type of geothermal resource from regulation and royalties. The stated intent of the exclusion:

> Your Committee finds that redefining "geothermal resources" in this manner would encourage new industries, such as the bottling and sale of mineral water and spa and resort development, by not subjecting them unnecessarily to the permit and other requirements applicable to geothermal development. Senate Standing Committee Report No. 2433 by the Committee on Energy and Natural Resources, on Senate Bill No. 3285. (Underlining added.)

Therefore, it is reasonable to conclude that the Legislature has consistently expressed its intent to encourage the use and production of geothermal resources for both electricity and non-electric purposes, by waiving or exempting royalties and, in the case of low-temperature direct uses such as spas, some permitting requirements.

Waiving or exempting royalties to encourage direct use would be consistent with this longstanding policy.

4.3 LEGAL AUTHORITY AND LEGISLATIVE INTENT FOR COUNTY ALLOCATION

4.3.1 State Legislation

In 1991, the Legislature mandated that thirty percent of all royalties received from geothermal resources shall be paid to the county in which mining operations covered by a state geothermal resource mining lease are situated. Since the county allocation is not an "add on" to the royalty paid to the State, it does not increase the financial costs of direct use.

This provision, which was enacted as Act 315, Session Laws of Hawaii, 1991, is contained in §182-7, Hawaii Revised Statutes. According to the Legislature:

> …a significant portion of geothermal royalties should be made available to the local government where the resource is located. Sharing this source of revenue mitigates the negative impacts of geothermal development. Standing Committee Report No. 382 by the Committee on Planning, Land and Water Use Management on Senate Bill No. 1523. (Underlining added.)

Neither §182-7, Hawaii Revised Statutes, or its legislative history provides guidance with regard to permissible uses or the level of mitigating activities which should be funded from the County allocation.

4.3.2 County of Hawaii Geothermal Funds

The County of Hawaii established two funds for revenue generated by geothermal activity. A Geothermal Asset Fund (§ 2-176, Hawaii County Code) was created in 1995 (Ordinance No. 95-74) for revenue generated pursuant to a condition of approval of Geothermal Resources Permit No. 2 issued to Puna Geothermal Venture on October 3, 1989. A Geothermal Relocation Program Fund (§ 2-177, Hawaii County Code) was established in 1996 (Ordinance No. 96-2.) The relocation program is funded with the County's share of geothermal royalties.

Section 2-176, Hawaii County Code, states that the purpose of the Geothermal Asset Fund is:

> Compensating persons impacted by geothermal energy development activities pursuant to the provisions incorporated in Geothermal Resource Permit No. 2.

No other purpose is stated. Rule 14 of the County Planning Commission's Rules of Practice and Procedure sets out the provisions and criteria for the Geothermal Asset Fund. Funding for this Geothermal Asset Fund is derived from Puna Geothermal Venture. As of December 31, 2006, there were $1,863,620 in the Geothermal Asset Fund. The County Planning commission had awarded approximately $14,202 from the Geothermal Asset Fund as of December 31, 2006; the last claim was paid in 2005.

Section 2-177, Hawaii County Code, establishes a Geothermal Relocation Program Fund for the relocation of owner-occupants residing near the Puna Geothermal Venture power plant. This provision permits the County of Hawaii to purchase the real properties of qualified owner-occupants and re-sell them. Rule 10-3 of the County Planning Department's Rules of Practice and Procedure, sets out the criteria for relocation:

> The geothermal relocation program shall initially apply only to owner-occupants and the highest priority shall be given to those individuals who:
>
> (a) Reside within a one (1) mile radius of the Puna Geothermal Venture facility;
> (b) Purchased their dwelling unit before October 3, 1989 or received a building permit for the dwelling unit before that date and final inspection for the dwelling has been completed by the Department of Public Works, Building Division; and
> (c) Express a desire to relocate.

Funding for this program is derived from three sources: the County's allocation of royalties, and the proceeds of re-sales and rentals of dwellings purchased. As of December 31, 2006, there were $2,205,097 in the fund. Through the program, the County has purchased four dwellings and resold them. The last purchase was made in the year 2003.

4.4 ISSUES RAISED – POTENTIAL ACTIONS

4.4.1 Expanding the Exemption for Direct Use

The goal of encouraging direct use of geothermal resources would be effectively advanced by clearly drafted legislation expanding the present exemption contained in §182-1, Hawaii Revised Statutes (resources under 150 degrees Fahrenheit not used for electricity). To address environmental and fiscal concerns, such an exemption would be narrowly drafted to list the uses which would be exempt, i.e., a use which is not specifically exempted would remain subject to permits and the payment of royalties. The legislation should also include clear criteria for an exemption. One potential exemption could be for facilities owned and controlled by the County to promote energy self-sufficiency, research, development, and other legitimate objectives.

4.4.2 Non Sale of Resource

If a producer were to give geothermal resources to a third party, either as a donation or to utilize excess resource, it could be argued that the requirement for the payment of royalties does not apply. Although §182-18, Hawaii Revised Statutes, imposes royalties for the "utilization" of geothermal resources, the board rule computes the royalty based on the sale or utilization by the lessee. The only non-sale situation in which the royalty would apply would be where the use would be by a plant owned or controlled by the lessee. Although the statute and rule do not define "control," the context of the rule implies a proprietary interest. Legislation could encourage direct use by making it clear that utilization that does not result in a financial gain by the lessee (directly or indirectly) is exempt from the royalty.

4.4.3 Expand Use of County Geothermal Funds

As stated above, the intent and purpose of the county allocation of royalties is to mitigate the negative impacts of geothermal development. Because the terms “negative impacts” and “mitigate” were not defined by the Legislature, the County was granted some discretion in the use of the funds.

As of this date, the County has elected to proceed cautiously. The class of potential beneficiaries of the Geothermal Relocation Program Fund—which is funded by royalties—was limited at its inception in 1996 by geography (one mile radius) and the date of acquisition. Unless the criteria contained in Rule 10-3 are expanded, the class of potential beneficiaries will continue to decrease.

The Geothermal Asset Fund does not contain money derived from royalties and thus is not guided by §182-7, Hawaii Revised Statutes. Its only stated purpose is to “compensate” persons affected by Geothermal Permit No. 2. County law would need to be modified to allow the funds to be used for other purposes.

It could be argued that direct use of geothermal resources may mitigate, for the County as a whole and for the community adjacent to geothermal development, the negative impact of geothermal electricity generation by creating economic opportunities without increasing reliance on fossil fuels. Geothermal power generation, is, by technical necessity, large in scale and in the scope of its impact on its location and adjacent property. There may be some direct uses which could utilize by-products of electricity generation, thus reducing its impact on the adjacent community. In the mid 1980s, the State established the Community Geothermal Technology Program with a federal grant. The purpose of the program was to support small business in the Puna District, encourage the use of waste heat and byproducts, and to allow community access to the geothermal resource.[1] A similar program, funded by the Geothermal Resource Program Fund or Geothermal Asset Fund in the

[1] “Hawaii and Geothermal, What Has been Happening”, Tonya L. Boyd, Geo-Heat Center Bulletin, September 2002.

Puna District, could support projects to encourage energy self-sufficiency and conservation, research, development and environmental protection – all of which would mitigate negative impacts of geothermal electricity generation.

A logical starting point for expanding the use of the County allocation of geothermal royalties is State legislation to clarify the intent and purpose of §182-7, Hawaii Revised Statutes. This provision could be amended to state that mitigation activities may include programs for energy conservation and self-sufficiency, research and development and the use of excess heat and by-products. Enactment of a broader and clear expression of legislative intent could pave the way for expansion of the purpose of the Geothermal Relocation Program.

Similarly, the County's Geothermal Asset Fund appears to be underutilized under the current restrictions for its use to "compensate" persons affected by Geothermal Permit No. 2. Expanding the legal uses of the Geothermal Asset Fund could provide the means to more broadly benefit the community affected by geothermal development.

Sample legislation for both the State and the County, intended to be a starting point for discussion (rather than the specific recommendations of this review), is attached as Appendix D. It is included to promote further conceptualization and refinement of policy.

CHAPTER 5 – ENGINEERING ANALYSIS

5.1 INTRODUCTION

This chapter will discuss the engineering analysis of geothermal direct use in the Kapoho / Pohoiki area. The engineering analysis was broken down into the following tasks:

- Discuss generalities of geothermal direct use systems.
- Describe a proposed geothermal direct use system.
- Describe major components of the proposed geothermal direct use system.
- Estimate the amount of heat required for the four potentially viable direct use enterprises identified in Chapter 2 – Geothermal Direct Use Enterprises.
- Estimate the amount of available geothermal heat.
- Design a hypothetical geothermal direct use enterprise park subdivision.

The engineering analysis was based on the assumption that waste heat will be available from a future geothermal application such as a power plant, ethanol plant, or some other future high temperature geothermal application.

It was determined that a hypothetical 15-acre geothermal direct use enterprise park located in the Kapoho / Pohoiki area is technically feasible. The hypothetical geothermal direct use enterprise park with an arbitrary selection of mixed tenants is estimated to have a peak heat rate demand of 11 million Btu/hr and an average heat rate demand of 6.6 million Btu/hr. A high temperature geothermal application, such as PGV's geothermal power plant, could provide 20 million Btu/hr of heat with a temperature drop as little as 10 degrees F in the spent injected geothermal fluids.

5.2 GEOTHERMAL DIRECT USE SYSTEM

Geothermal direct use systems transfer heat from a geothermal heat source to a geothermal direct use enterprise. Sometimes, geothermal heat is transferred through direct contact with a geothermal fluid, as with natural hot springs where people come in direct contact with geothermal water. Other times, geothermal heat is transferred through direct contact with a secondary or tertiary heated fluid, as with greenhouses where heat is transferred to air that is circulated in the greenhouse. See Figure 5-1 for a schematic diagram of a geothermal direct use system that transfers heat from a geothermal fluid to a direct use enterprise. See Figure 5-2 for a schematic diagram of a geothermal direct use system that transfers heat from a secondary fluid to a direct use enterprise. Geothermal fluid chemistry, economics, and end user requirements are among the factors that dictate whether geothermal fluids or secondary fluids are appropriate for the transfer of heat to geothermal direct use enterprises. Geothermal fluids from deep, high-pressure resources in Hawaii are often times corrosive and necessitate the use of exotic materials for equipment. These high-temperature geothermal brines can be saturated with silica, cause scaling, and plug metal piping and equipment. Isolating these geothermal brines near their source with a heat exchanger can reduce the amount of equipment exposed to corrosive, scale-causing geothermal brine.

Geothermal fluids are commonly located hundreds to thousands of feet below ground. The shallower resources, which are not under pressure, require downhole heat exchangers or electrical pumps to extract geothermal heat. Using a downhole heat exchanger can reduce the amount of pump power required to extract geothermal heat, and can also eliminate the need for an injection well to dispose of spent geothermal fluids.

Geothermal direct use enterprise requirements vary and often necessitate the transfer of heat to another fluid before the heat can be used. The most

ENGINEERING ANALYSIS
SCHEMATIC SYSTEM DIAGRAM

FIGURE 5–1: GEOTHERMAL DIRECT USE – DIRECT CONTACT WITH GEOTHERMAL FLUID

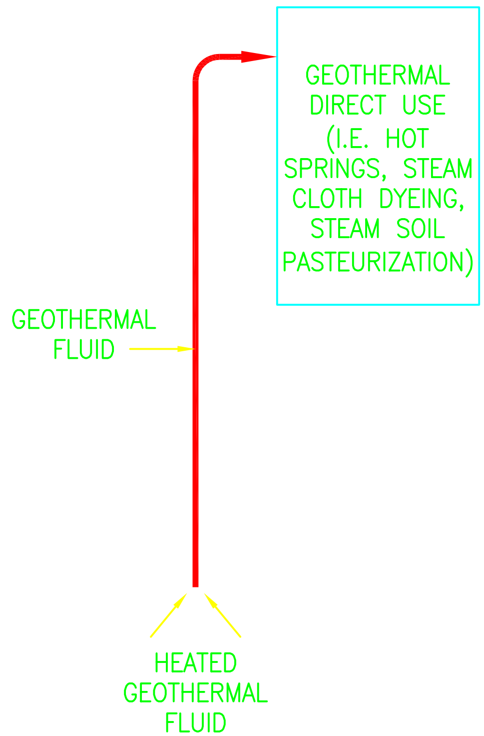
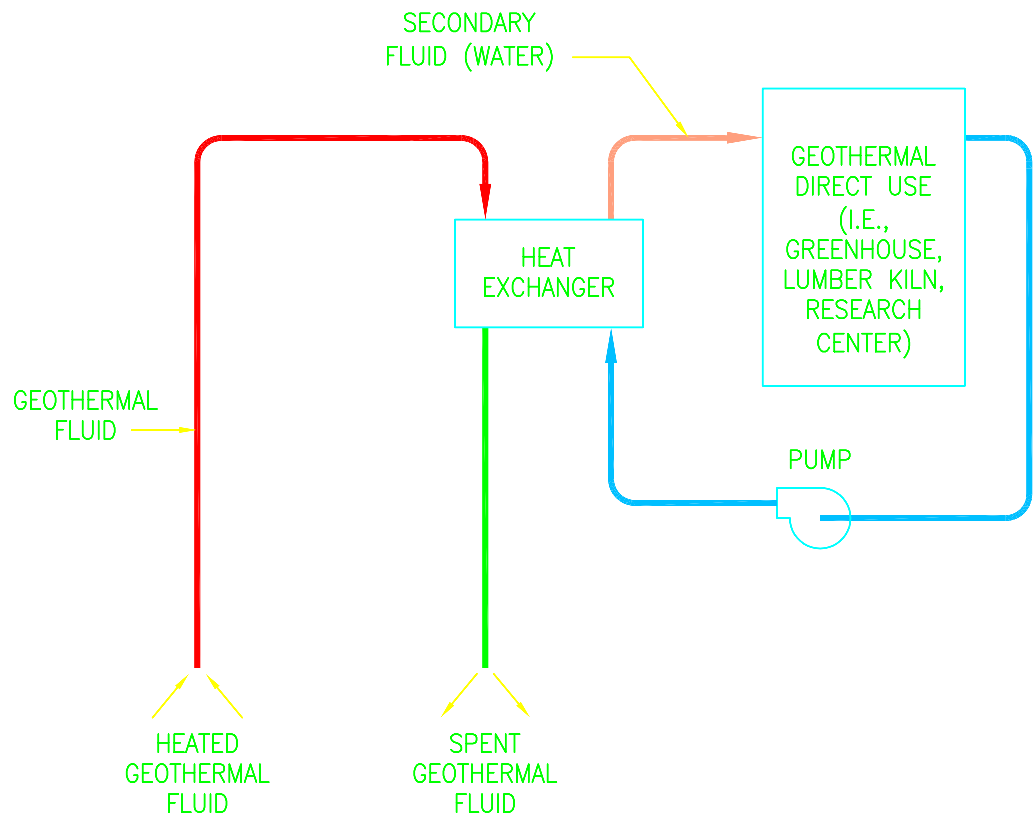


FIGURE 5–2: GEOTHERMAL DIRECT USE – DIRECT CONTACT WITH SECONDARY FLUID



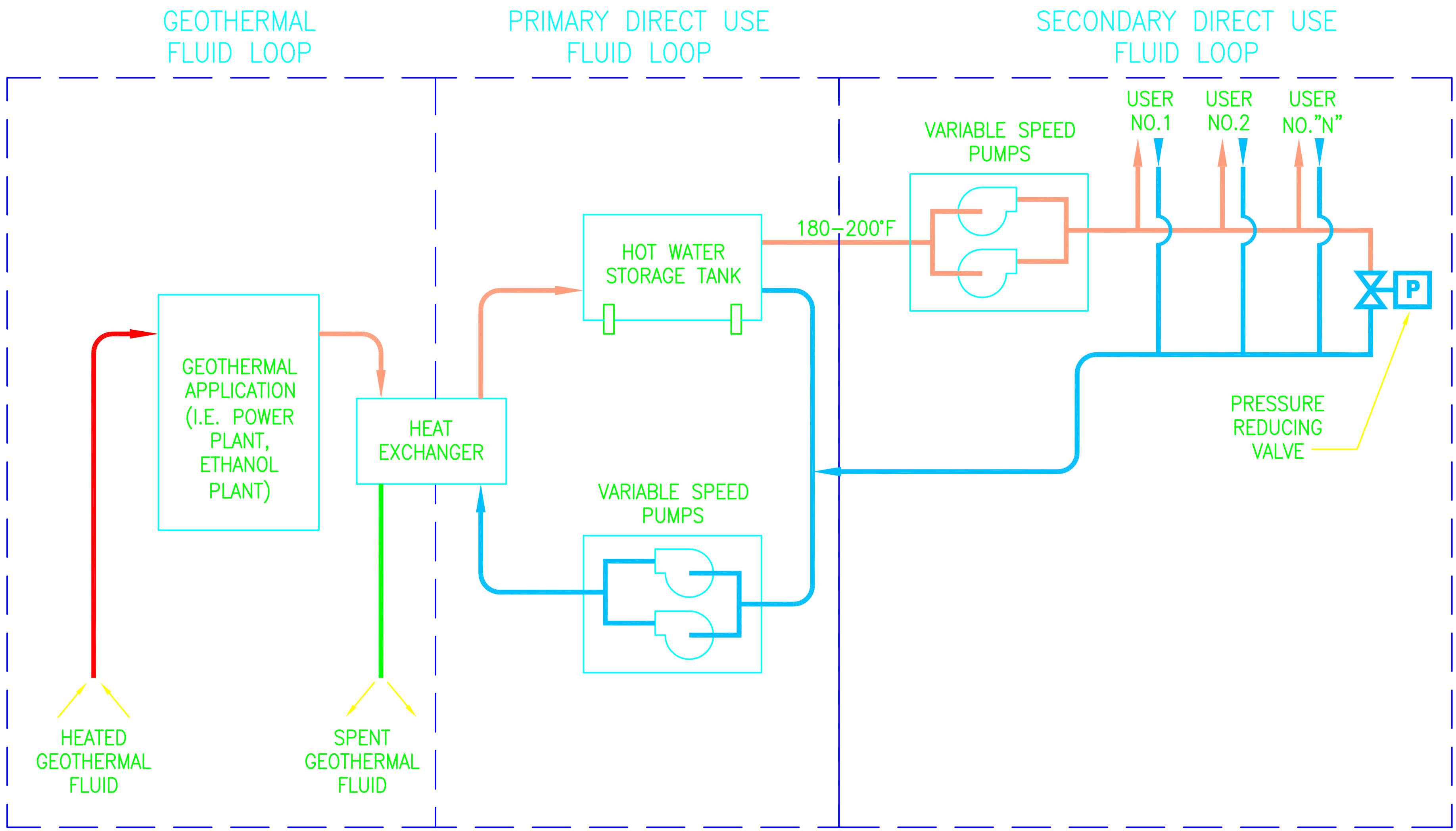
common secondary fluids used in geothermal direct use systems are steam, water, and air. In all of these cases, the transfer of geothermal heat to another fluid can save money and power, and improve the usability of the heat.

5.3 PROPOSED GEOTHERMAL DIRECT USE SYSTEM

A geothermal direct use system for the hypothetical geothermal enterprise park would need to be robust and flexible. It would need to be able to adapt to dynamic conditions where the heat source temperatures may change gradually, and heat consumption rates may change rapidly. It would need to be modular in nature and have provisions for expansion without sacrificing operational efficiency. It would need to be reliable and satisfy heat demands with dependable constant temperatures.

A geothermal direct use system employing three fluid loops was selected for evaluation based on the assumed design requirements. The first fluid loop is the geothermal fluid loop and would consist of the geothermal fluid, piping, and heat exchanger. The geothermal fluid loop would serve as the heat source for the geothermal direct use system and supply heat through a heat exchanger. The second fluid loop is the primary direct use fluid loop and would consist of the secondary fluid, hot water storage tank, pumps, piping, and heat exchanger. Pumps would circulate cold secondary fluid from the hot water storage tank to the heat exchanger and back to the hot water storage tank. The primary direct use fluid loop would be responsible for receiving and regulating the transfer of heat from the geothermal fluid to the secondary fluid. The third fluid loop is the secondary direct use fluid loop and would consist of the secondary fluid, pumps, and piping. Pumps would circulate hot secondary fluid from the hot water storage tank, to the geothermal direct use enterprises, and back to the hot water storage tank for reheating. The secondary direct use fluid loop would be responsible for distribution of heat to direct use enterprises. Figure 5-3 illustrates the three loops: geothermal fluid loop, primary direct use fluid loop, and secondary direct use fluid loop.

ENGINEERING ANALYSIS
FIGURE 5-3: SCHEMATIC SYSTEM DIAGRAM



5.4 GEOTHERMAL DIRECT USE SYSTEM COMPONENTS

Each major component shown on Figure 5-3 is composed of many smaller components. The following describes the major and selected minor smaller components.

5.4.1 Heat Exchanger

The heat exchangers would serve a dual function in the proposed geothermal direct use system. They would be responsible for transferring heat from a geothermal fluid to a secondary fluid, and also for protecting the geothermal direct use system components from corrosive, scale-causing geothermal brines. The heat exchanger would be constructed of an appropriate corrosion- and scale-resistant material, such as stainless steel, and would be equipped with the following:

- Multiple heat exchangers for redundancy and ease of maintenance.
- Shutoff valves for maintenance.
- Control valves to control flow.
- Temperature and pressure relief valve(s) to relieve pressure in the event of overheating.

5.4.2 Hot Water Storage Tank

The hot water storage tank would store a small amount of hot water, and decouple the direct use fluid loops in the proposed geothermal direct use system. Decoupling the direct use loops into primary and secondary loops would allow the system to adjust quickly to temperature and flow changes. The hot water storage tank would be constructed of lined steel, and would be equipped with the following:

- Shutoff valves for maintenance.
- Air separator to remove air from the water.

- Makeup water system (backflow preventer, pressure-reducing valve) to replace secondary fluids lost through leaks.
- Insulation to minimize heat losses.
- Temperature and pressure relief valve(s) to relieve pressure in the event of overheating.
- Expansion tank to account for fluid expansion and contraction.

5.4.3 Pumps (Primary and Secondary Direct Use Loops)

Pumps would provide the means to circulate secondary fluids between the heat exchanger and the water storage tank in the proposed geothermal direct use system. Pumps would also provide the means to circulate and distribute heated water to geothermal direct use enterprises. The pumps would be constructed of standard materials and would be equipped with the following:

- Shutoff valves for maintenance.
- Pump control, check, and air release valves for operation.
- Variable speed drives (VSD) to allow the pumps to operate at various speeds, match the hot water demand, and minimize wasted energy.
- Building enclosure to protect equipment from the elements.
- Ventilation system to cool the building enclosure.

5.4.4 Pipes

Pipes would provide a conduit through which fluids could be circulated throughout the system in the proposed geothermal direct use system. The pipes would be constructed of a material that could withstand elevated fluid temperatures and corrosion. Possible material candidates include fiberglass reinforced plastic (FRP), high-density polyethylene (HDPE), and crosslinked polyethylene (PEX). Metals were removed from consideration because of susceptibility to corrosion. Many plastics were removed from consideration because of insignificant strength at elevated temperatures. Pipes would likely be installed underground and equipped with the following:

- Shutoff valves to isolate portions of the system.
- Insulation to minimize heat losses.

5.4.5 Controls

Computerized controls would provide a means to control, monitor, and protect the proposed geothermal direct use system. The controls could be manufactured and programmed by a single entity and would likely be furnished with the following:

- Laptop computer to interface with the controls.
- Uninterrupted power supply (UPS) to shut down the system in the event of loss of electricity.
- Phone line to automatically contact an operator during off-hours in the event of an emergency.
- Building enclosure to protect equipment from the elements.

5.5 HEAT REQUIRED FOR GEOTHERMAL DIRECT USE ENTERPRISES

Greenhouse bottom heating, pasteurization of potting media, biodiesel production, and lumber kilns were determined to be the potentially viable direct use enterprises by the analysis discussed in Chapter 2 – Geothermal Direct Use Enterprises. All four direct use enterprises were further analyzed by this chapter to estimate their heat demand. Table 5-1 summarizes the estimated heat demand for each of the four direct use enterprises. It should be noted that, due to the complexity of the energy analysis, many assumptions were made to simplify the analysis. See the self-titled subsections for assumptions and calculations.

TABLE 5-1: ESTIMATED GEOTHERMAL DIRECT USE HEAT REQUIREMENTS

GEOTHERMAL DIRECT USE	UNIT OF DIRECT USE	HEAT DEMAND (BTU/HR)		EQUIVALENT BARRELS OF OIL PER UNIT*
		PER UNIT OF DIRECT USE	OF POTENTIAL GROWTH	
Greenhouse Bottom Heating	Acre per year	5.9×10^5 Ave. 1.1×10^6 Max.	Unlimited	1.4×10^3
Pasteurization of Potting Media (First 10 Minutes)	1,000 pounds	1.4×10^5	Unlimited	3.8×10^{-2}
Pasteurization of Potting Media (After 10 Minutes)		8.6×10^1		2.4×10^{-5}
Biodiesel Production	10,000 gallons per year	4.4×10^4	Unlimited	$1.1 \text{X} 10^2$
Lumber Kiln (Average Heat Demand)	200,000 board feet per year (Approximately 10% of estimated sustainable local production capacity)	3.0×10^4	3.0×10^5	72
Lumber Kiln (Initial Heat Demand, First 24 Hours)		8.6×10^5	8.6×10^6	5.6

*Equivalent barrels of crude oil based on energy content of 5,800,000 Btu per barrel (Energy Calculator 2005) and a water heating efficiency of 63%.

5.5.1 Greenhouse Bottom Heating Calculations

The following documents the assumptions and calculations used to estimate the heat demand of greenhouse bottom heating:

Assumptions:

- 1-acre (43,560 ft^2) greenhouse operation
- Half of greenhouse consists of soil, half consists of walkways.
- Soil design temperature = 80 degrees F.
- Average outdoor temperature = 70 degrees F.
- Average outdoor low temperature = 61 degrees F.
- Soil temperature is constant.
- Heat resistance in upwards direction $= 0.61\left(\frac{ft^2 * {}^{o}F * hr}{Btu}\right)$ reference 2005 ASHRAE Fundamentals, Page 25.2, Table 1

- Heat resistance in downwards direction $= 0.92\left(\frac{ft^2 * {}^{o}F * hr}{Btu}\right)$

  reference 2005 ASHRAE Fundamentals, Page 25.2, Table 1

Calculate average heat requirements to maintain design soil temperatures:

$$q = UA\Delta T$$

Where: q = heat flow (BTU/hr)

U = heat conductance = $\frac{1}{R}$

R = Resistance $\left(\frac{ft^2 * {}^{o}F * hr}{Btu}\right)$

ΔT = Temperature difference between soil and outside air

$$q = \left(\frac{Btu}{0.61\ ft^2 * {}^{o}F * hr}\right)\left(\left(\frac{1}{2}\right)\left(43{,}560\ ft^2\right)\right)\left(80 - 70^{o}F\right) + \left(\frac{Btu}{0.92\ ft^2 * {}^{o}F * hr}\right)\left(\left(\frac{1}{2}\right)\left(43{,}560\ ft^2\right)\right)\left(80 - 70^{o}F\right) = 5.9x10^5\ \frac{Btu}{hr}$$

Calculate maximum heat requirements to maintain design soil temperatures:

$$q = \left(\frac{Btu}{0.61\ ft^2 * {}^{o}F * hr}\right)\left(\left(\frac{1}{2}\right)\left(43{,}560\ ft^2\right)\right)\left(80 - 61^{o}F\right) + \left(\frac{Btu}{0.92\ ft^2 * {}^{o}F * hr}\right)\left(\left(\frac{1}{2}\right)\left(43{,}560\ ft^2\right)\right)\left(80 - 61^{o}F\right) = 1.1x10^6\ \frac{Btu}{hr}$$

5.5.2 Pasteurization of Potting Media Calculations

The following documents the assumptions and calculations used to estimate the heat demand of pasteurization of potting media:

Assumptions:

- 1,000 pounds of potting media, specific density of 1.5 (95 lbs/cubic foot), specific heat 0.25 Btu/lbm/deg F
- Design potting media pasteurization chamber temperature = 160 degrees F
- 50% of pasteurization chamber is free open space for access and airflow
- Average outdoor air temperature = 75 degrees F dry bulb
- Chamber is located in a naturally ventilated warehouse

- Chamber is insulated with approximately R-20 insulation
- 1 hour sterilization duration
- 10-minute heat up period

Calculate size of pasteurization chamber to process 1,000 pounds of potting media:

$$V_{chamber} = \frac{V_{potting\ media}}{\text{Free Area}}$$

$$V_{potting\ media} = \frac{W_{potting\ media}}{p}$$

Where: V = volume (ft^3)
W = weight (lb)
p = density (lb/ft^3)

$$V_{chamber} = \frac{(1{,}000\ \text{pounds})}{\left(95\ \frac{\text{pounds}}{ft^3}\right)(50\%\ \text{Free Area})} = 21\ ft^3$$

Calculate amount of heat necessary to heat potting media from 75 to 160 degrees F:

$$q = \frac{W_{potting\ media} c_p \Delta T}{t}$$

Where: q = heat flow rate (Btu/hr)
c_p = specific heat (Btu/lbm/deg F)
ΔT = change in temperature from 75 to 160 degrees F
t = time period (hours)

$$q = \frac{(1{,}000\ \text{pounds per hour})\left(0.25\ \frac{\text{Btu}}{\text{lbm}*^{o}\text{F}}\right)(160 - 75\ ^{o}\text{F})}{(10\ \text{min})\left(\frac{1\ \text{hr}}{60\ \text{min}}\right)} = 1.3x10^{5}\ \frac{\text{Btu}}{\text{hr}}$$

Calculate amount of heat necessary to heat outside air from 75 to 160 degrees F:

$$q = 1.08 Q \Delta T$$

Where: q = heat flow rate (Btu/hr)
ΔT = change in temperature from 75 to 160 degrees F

$$q = (1.08)\left(\frac{(21\,ft^3)(50\%)}{\text{per hour}}\right)\left(\frac{1\,\text{hour}}{60\,\text{minutes}}\right)(160 - 75\ ^oF) = 5.8x10^3\ \text{Bth/hr}$$

<u>Calculate dimensions of chamber assuming square foot print and 10 foot high ceiling</u>:

$$V_{chamber} = (w)(l)(h)$$

$$w = l$$

$$w = \sqrt{\frac{V_{chamber}}{h}}$$

Where: w = width of chamber interior (ft)
l = length of chamber interior (ft)
h = height of chamber interior (ft)

$$w = \sqrt{\frac{21\,ft^3}{10\ ft}} = 0.5\ \text{feet}$$

<u>Estimate heat loss through chamber walls and roof</u>:

$$q = U\Sigma A\Delta T$$

Where: q = heat flow (BTU/hr)
U = heat conductance = $\frac{1}{R}$
ΣA = sum of chamber surface areas (ft^2)
R = Resistance $\left(\frac{ft^2 *^o F * hr}{Btu}\right)$

ΔT = Temperature difference between chamber air and outside air

$$q = \left(\frac{Btu}{20\ ft^2 *^o F * hr}\right)((0.5\ ft * 0.5\ ft) + (4)(0.5\ ft * 10\ ft))(160 - 75\ ^oF)$$

$$= 8.6x10^1\ \frac{Btu}{hr}$$

<u>Calculate total heat requirement for 1,000 pounds of potting media during first 10-minutes</u>:

$q = 1.3x10^5 + 5.8x10^3$ Btu/hr + $8.6x10^1$ Btu/hr = $1.4x10^5$ Btu/hr

Calculate total heat requirement for 1,000 pounds of potting media after first 10-minutes:

$q = 8.6x10^1$ Btu/hr = $8.6x10^1$ Btu/hr

5.5.3 Biodiesel Production Calculations

The following documents the assumptions and calculations used to estimate the heat demand of biodiesel production:

Assumptions:

- 10,000 gallons of biodiesel production per year
- 38,300 Btu required to produce one gallon of biodiesel (Radich, 2004)
- Biodiesel is produced 24 hours a day

Calculate amount of heat required to produce 10,000 gallons of biodiesel per year:

$$q = \left(\frac{10{,}000 \text{ gallons biodiesel}}{\text{year}}\right)\left(\frac{1 \text{ year}}{365 \text{ days}}\right)\left(\frac{1 \text{ day}}{24 \text{ hours}}\right)\left(\frac{38{,}300 \text{ Btu}}{\text{gallon biodiesel}}\right)$$

$$= 4.4x10^4 \frac{\text{Btu}}{\text{hr}}$$

5.5.4 Lumber Kiln (Average Demand) Calculations

The following documents the assumptions and calculations used to estimate the average heat demand of lumber kilns:

Assumptions:

- Local hardwood capacity of 2,000,000 Board Feet (BF) per year (Dudley, 2004)
- 10% of local hardwood capacity is dried by geothermal kiln
- 12 BF = 1 cubic foot of wood (Dudley, 2004)
- Density of wood is 40 pounds per cubic foot (Dudley, 2004)
- 50% of kiln is free open space for access and airflow
- 15% initial moisture content
- 4% final moisture content (Leaman, 1989)
- Required relative humidity in kiln to achieve 4% equilibrium moisture content = 20% (Reeb, 2006)
- Design kiln temperature = 150 degrees F dry bulb, 101.5 degrees F wet bulb, 20% RH, 0.03319 humidity ratio, 16.19 cubic feet per pound specific volume

- Average outdoor air temperature = 75 degrees F dry bulb, 70 degrees F wet bulb, 78% RH, 0.01875 humidity ratio, 13.80 cubic feet per pound specific volume
- Kiln is located in a naturally ventilated warehouse
- Kiln is insulated with approximately R-20 insulation
- 24 hour, 7 day a week operation

Calculate pounds of green wood that will be kiln dried per year:

$$W_{wood} = BF * p$$

Where: W = weight (lbs)
BF = board feet
p = density of wood

$$W_{wood} = (10\%)(2,000,000\ BF)\left(\frac{1 ft^3}{12\ BF}\right)\left(\frac{40\ pounds}{ft^3}\right) = 6.67x10^5\ pounds$$

Calculate pounds of water moisture that must be removed per year:

$$W_{water} = W_{wood} * 15\%\ MC = (6.67x10^5\ pounds)(15\% - 4\%\ MC)$$
$$= 7.3x10^4\ pounds$$

Calculate pounds air that must be used to remove required amount of water per year:

$$W_{air} = \frac{W_{water}}{(HR_{150\ deg\ F} - HR_{84\ deg\ F})}$$

Where: HR = humidity ratio $\left(\frac{pounds\ of\ moisture}{pounds\ of\ dry\ air}\right)$

$$W_{air} = \frac{7.3x10^4\ pounds\ of\ water}{\left(0.03319 - 0.01875\ \frac{pounds\ of\ moisture}{pounds\ of\ dry\ air}\right)}$$
$$= 5.1x10^6\ pounds\ of\ dry\ air$$

Calculate cubic feet per minute of outside air required to dry wood:

$$Q = W_{air} * v$$

Where: Q = airflow rate (cfm)
v = specific volume of air (ft^3/lb)

$$Q = \left(\frac{5.1x10^{6}\ \text{pounds}_{\text{dry air}}}{\text{year}}\right)\left(\frac{13.80\ \text{ft}^{3}}{\text{pound}_{\text{dry air}}}\right)\left(\frac{1\,\text{year}}{365\ \text{days}}\right)\left(\frac{1\,\text{day}}{24\,\text{hours}}\right)\left(\frac{1\,\text{hour}}{60\,\text{min}}\right)$$

$$= 134\ \text{cfm}$$

<u>Calculate amount of heat necessary to heat outside air from 75 to 150 degrees F</u>:

$$q = 1.08Q\Delta T$$

Where: q = heat flow rate (Btu/hr)
ΔT = change in temperature from 75 to 150 degrees F

$$q = (1.08)(134\ \text{cfm})(150 - 75\ {}^{o}\text{F}) = 1.1x10^{4}\ \text{Bth/hr}$$

<u>Calculate size of wood kiln to process 10% of local hardwood capacity (200,000 BF)</u>:

$$V_{\text{kiln}} = \frac{V_{\text{wood}}}{\text{Free Area}}$$

Where: V = volume (ft^3)
p = density (lb/ft^3)

$$V_{\text{kiln}} = \frac{(10\%)(2{,}000{,}000\ \text{BF})\left(\frac{1\,\text{ft}^{3}}{12\,\text{BF}}\right)}{50\%\ \text{Free Area}} = 3.3x10^{4}\ \text{ft}^{3}$$

<u>Calculate dimensions of kiln assuming square foot print and 20 foot high ceiling</u>:

$$V_{\text{kiln}} = (w)(l)(h)$$

$$w = l$$

$$w = \sqrt{\frac{V_{\text{kiln}}}{h}}$$

Where: w = width of kiln interior (ft)
l = length of kiln interior (ft)
h = height of kiln interior (ft)

$$w = \sqrt{\frac{3.3x10^{4}\ \text{ft}^{3}}{20\ \text{ft}}} = 41\,\text{feet}$$

Estimate heat loss through kiln walls and roof:

$$q = U\Sigma A\Delta T$$

Where: q = heat flow (BTU/hr)

U = heat conductance = $\frac{1}{R}$

ΣA = sum of kiln surface areas (ft^2)

R = Resistance $\left(\frac{ft^2 * {}^oF * hr}{Btu}\right)$

ΔT = Temperature difference between kiln air and outside air

$$q = \left(\frac{Btu}{20\ ft^2 * {}^oF * hr}\right)\left((41\,ft * 41\,ft) + (4)(41\,ft * 20\,ft)\right)(150 - 75\ {}^oF)$$

$$= 1.9x10^4\ \frac{Btu}{hr}$$

Calculate total average heat requirement for 200,000 BF per year:

q = $1.1x10^4$ + $1.9x10^4$ Btu/hr = $3.0x10^4$ Btu/hr

5.5.5 Lumber Kiln (First 24 Hour Demand) Calculations

The following documents the assumptions and calculations used to estimate the first 24 hour heat demand of lumber kilns:

Assumptions:

- Specific heat of hardwood = 0.40 Btu/lbm/deg F
- Heat required to heat initial air is negligible
- 24-hour heat up period
- See Lumber Kiln Calculations for supporting calculations

Calculate amount of heat necessary to 200,000 BF of lumber from 75 to 150 degrees F:

$$q = \frac{W_{lumber} c_p \Delta T}{t}$$

Where: q = heat flow rate (Btu/hr)

c_p = specific heat (Btu/lbm/deg F)

ΔT = change in temperature from 83 to 160 degrees F

t = time period (hours)

$$q = \frac{\left(6.67x10^5 \text{ pounds}\right)\left(0.40 \frac{\text{Btu}}{\text{lbm}*^\circ\text{F}}\right)\left(150 - 75\ ^\circ\text{F}\right)}{\left(24\text{ hr}\right)}$$

$$= 8.3x10^5 \frac{\text{Btu}}{\text{hr}}$$

Calculate total average heat requirement for first 24 hours of lumber kiln operation:

$q = 3.0x10^4 + 8.3x10^5$ Btu/hr = $8.6x10^5$ Btu/hr

5.6 AVAILABLE HEAT

Chapter 3 – Geothermal Heat Resources identified future applications of high temperature geothermal heat as the only potentially viable source of heat for a geothermal direct use enterprise park. PGV was retained as a potential but unlikely source of heat. Existing wells were removed from consideration because of insufficient fluid temperatures and/or insufficient quantity of heated fluids. New wells were removed from consideration because of the high cost of exploration and drilling.

Available heat calculations were based on existing PGV operations for the purpose of illustrating the amount of waste heat that may be available for geothermal direct use from a high temperature geothermal application. It was assumed that the extraction of heat from spent geothermal fluids would need to be limited in terms of temperature drop to avoid scaling problems. Scaling problems can occur when the temperature of a geothermal fluid saturated with silica is reduced to a point that allows silica to precipitate out of solution. The following assumptions were made to calculate the amount of waste heat that may be available for geothermal direct use from a high temperature geothermal application:

- Geothermal fluid flow rate equals 4,000 gpm based on PGV's existing operations.
- Spent geothermal fluid temperature will be a minimum of 200 degrees F.

- Direct use secondary fluid will be limited in temperature to 200 degrees F to avoid handling of steam or pressurizing the system. (Design choice)

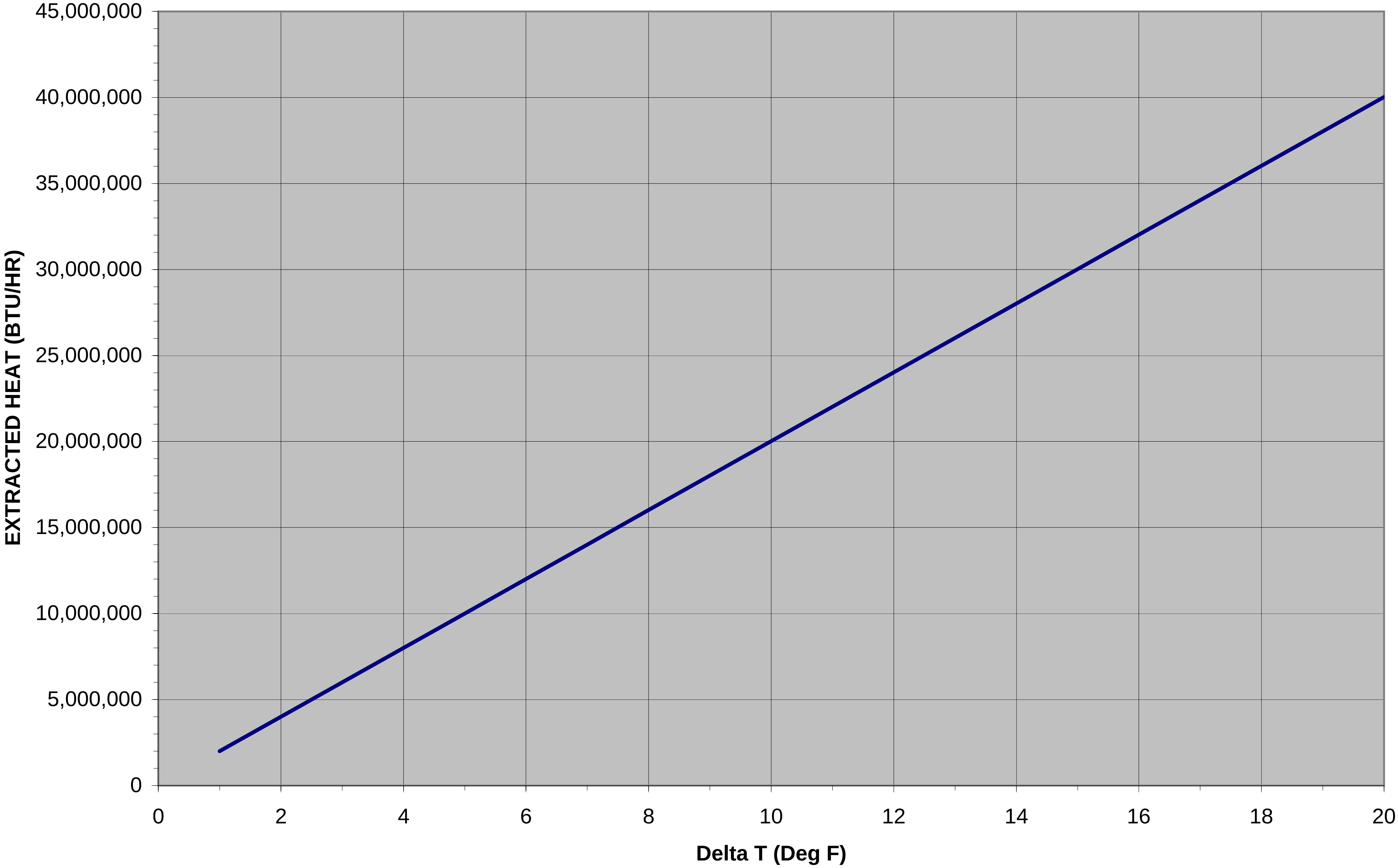
Chart 5-1 and Table 5-2 show the relationship of geothermal fluid temperature drop, at a flow rate of 4,000 gpm, to the amount of heat energy that can be extracted. Approximately 20 million Btu/hr can be extracted from 4,000 gpm of spent geothermal fluid experiencing a 10 degree F drop in temperature. Twenty million Btu/hr can provide enough heat for 18 acres of greenhouse bottom heating at a peak heat consumption rate of $1.1x10^6$ Btu/hr per acre, pasteurize over 140 tons of potting media per day at a heat consumption rate of $1.4x10^5$ Btu/hr, produce approximately 4.5 million gallons of biodiesel per year at a heat consumption rate of 38,300 Btu per gallon, dry more than 2 million BF of lumber annually (the estimated sustainable Hawaii State lumber production capacity) at a heat consumption rate of $3.0x10^4$ Btu/hr per 200,000 BF, or provide for a combination of these enterprises.

5.7 HYPOTHETICAL GEOTHERMAL DIRECT USE ENTERPRISE PARK

The Kapoho / Pohoiki area is generally zoned agricultural or conservation district land. It is anticipated that a portion of land may need to be rezoned to allow for commercial use. The County is allowed to rezone up to 15 acres of land without consulting the state land use board under certain conditions, and was selected as the basis for the hypothetical enterprise park size. A 15-acre parcel can be subdivided into approximately 13 one-acre lots (see Figure 5-4 for a possible subdivision layout with road and waterline). A hypothetical geothermal direct use enterprise park may have the following tenants:

- 5-acres greenhouse bottom heating operations ($1.1x10^6$ Btu/hr maximum per acre).
- 1-acre soil pasteurization operation (1,000 tons per year, $1.4x10^5$ Btu/hr intermittent use).

ENGINEERING ANALYSIS
CHART 5-1: HEAT EXTRACTION POTENTIAL FROM PGV GEOTHERMAL FLUID FLOW RATE EQUAL 4,000 GPM



ENGINEERING ANALYSIS
TABLE 5-2: HEAT EXTRACTION POTENTIAL FROM PGV GEOTHERMAL FLUID FLOW RATE EQUAL 4,000 GPM

Delta T (deg F)	Heat Extracted (Btu/hr)
1	2,001,600
2	4,003,200
3	6,004,800
4	8,006,400
5	10,008,000
6	12,009,600
7	14,011,200
8	16,012,800
9	18,014,400
10	20,016,000
11	22,017,600
12	24,019,200
13	26,020,800
14	28,022,400
15	30,024,000
16	32,025,600
17	34,027,200
18	36,028,800
19	38,030,400
20	40,032,000

Geothermal Fluid (Heat Source Flow Rate) = 4,000 gpm (based on PGV injection flow rates)

Sample Calculations

Calculate heat extracted from geothermal fluid:

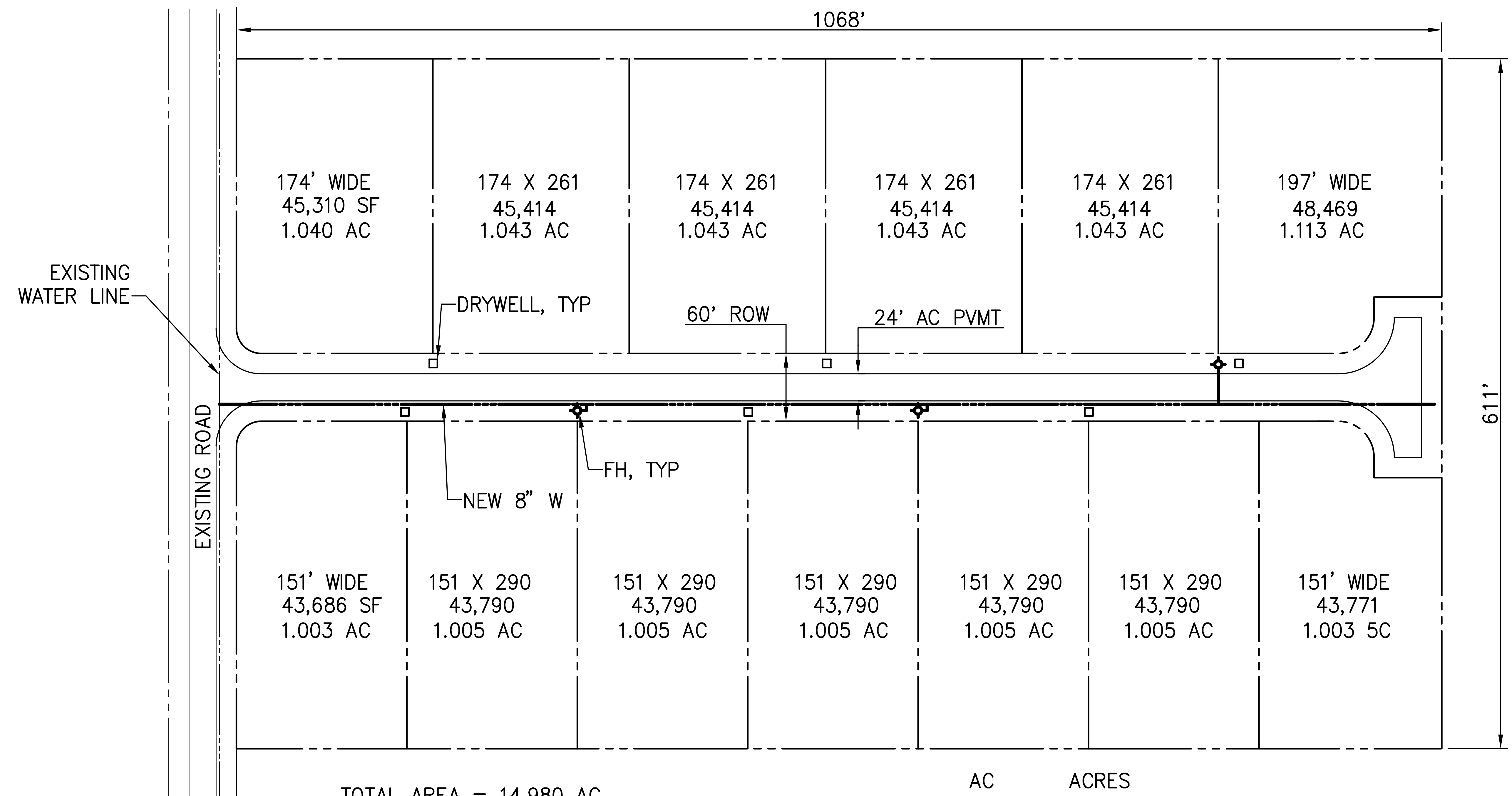
$q = Qc_p(\text{delta T})$

Where: q = heat flow rate (Btu/hr)
cp = specific heat of water (Btu/lbm/deg F)
delta T = temperature fall (degrees F)

q **= (4,000 gpm)(1.0 Btu/lbm/degrees F)(1 degree F)(60 min/hr)(8.34 lbm/gallon)**
= 2,001,600 Btu/hr

ENGINEERING ANALYSIS

FIGURE 5–4: GEOTHERMAL DIRECT–USE ENTERPRISE PARK SUBDIVISION



TOTAL AREA = 14.980 AC
TOTAL LOT AREA = 13.356 AC
TOTAL ROAD AREA = 1.624 AC

AC	ACRES
FH	FIRE HYDRANT
AC PVMT	ASPHALT CONCRETE PAVMENT
ROW	RIGHT–OF–WAY
SF	AQUARE FEET
TYP	TYPICAL
W	WATER

- 1-acre biodiesel production operation (100,000 gallons per year, 4.4×10^5 Btu/hr).
- 1-acre lumber kiln operation (200,000 BF annually, 8.6×10^5 Btu/hr maximum).
- 1-acre University of Hawaii research facility (1.1×10^6 Btu/hr assumed based on bottom heating).
- 1-acre community center with a commercial kitchen, rented drying facilities, and laundromat (8.6×10^5 Btu/hr assumed based on lumber kiln initial heat demand).
- 1-acre geothermal direct use equipment, pump house, control building, parking, etc.
- 2-acres for future development (1.1×10^6 Btu/hr assumed based on bottom heating).

The maximum heat demand rate of a hypothetical 15-acre geothermal direct use enterprise park is estimated to be approximately 11 million Btu/hr. The average heat demand rate of a hypothetical 15–acre geothermal direct use enterprise park is estimated to be approximately 6.6 million Btu/hr, which is the equivalent of 1.8 barrels of crude oil per hour or 15,800 barrels of crude oil per year. One barrel of crude oil has a heating capacity of 3.654 million Btu based on an energy content of 5.8 million Btu per barrel (Energy Calculator 2005) and an assumed water heating efficiency of 63%.

5.8 SUMMARY OF ENGINEERING ANALYSIS

Geothermal direct use systems transfer heat from a geothermal heat source to direct use enterprises such as greenhouses, pasteurization of potting media, biodiesel production, and lumber kilns. A geothermal direct use system for a hypothetical geothermal direct use enterprise park would need to be robust, flexible, and scalable. One proposed geothermal direct use system would extract waste heat from geothermal brines after the fluids were used by a high temperature geothermal heat application. The heat would be transferred to a secondary fluid and circulated throughout the geothermal direct use enterprise park. Design features such as variable frequency drives, redundant systems, decoupled fluid loops, hot water storage tank, insulation, and digital controls would be incorporated to improve the overall system performance.

It has been determined that a geothermal direct use enterprise system extracting heat from a high temperature geothermal application such as PGV's power plant, could provide sufficient heat to support a 15-acre geothermal direct use enterprise park with a temperature drop as little as 5 to 10 degrees F in the geothermal fluids. Based on the engineering analysis, it appears a geothermal direct use enterprise park is technically viable in the Kapoho / Pohoiki area provided that affordable access to geothermal heat is available.

CHAPTER 6 – ENGINEERING COST ANALYSIS

6.1 INTRODUCTION

This chapter will discuss the engineering cost analysis of geothermal direct use in the Kapoho / Pohoiki area and determine if a 15-acre geothermal direct use enterprise park could be economically feasible. The engineering cost analysis was focused on the economic feasibility of a 15-acre enterprise park and geothermal direct use system. The economic feasibility of individual geothermal direct use businesses was not evaluated. The engineering cost analysis of the 15-acre geothermal direct use enterprise park was broken down into the following tasks:

- Identify and estimate both geothermal and non-geothermal related costs to develop a 15-acre geothermal direct use enterprise park in the Kapoho / Pohoiki area.
- Estimate the potential revenue a 15-acre geothermal direct use enterprise park would generate based on rates that could be charged for leases and geothermal heat.
- Qualitatively define economic feasibility and determine the degree of economic feasibility of a 15-acre geothermal direct use enterprise park located in the Kapoho / Pohoiki area.

A 15-acre geothermal direct use enterprise park will cost approximately $12.5 million to develop and construct, and $738,000 to operate and maintain in the Kapoho / Pohoiki area. Revenues are estimated to be $1.21 million based on a lease rate of $200/acre-year and a geothermal heat rate priced at $1.32 per therm (100,000 Btu), a 50% discount of the prevailing average fuel rate of diesel and propane. The anticipated payback period for the project is 26 years without financial subsidies. The costs and payback period could increase if a number of assumed favorable conditions do not occur. The payback period could be reduced to 7 years if $9.2 million in financial subsidies are provided.

It was concluded that a 15-acre geothermal direct use enterprise park located in the Kapoho / Pohoiki area is at best only marginally economically feasible. "Economically feasible" is defined by this study as the ability to deliver heat energy at a reasonable rate to geothermal direct use customers while maintaining the ability to indefinitely sustain system operations and provide a small return.

6.2 GEOTHERMAL DIRECT USE ENTERPRISE COSTS

Geothermal direct use enterprise park costs were identified and grouped into two categories: capital costs and operation & maintenance (O&M) costs. Capital costs include all of the planning, design, permitting, and construction costs required to develop and construct a 15-acre geothermal direct use enterprise park. O&M costs include all of the maintenance, taxes, utility fees, and management fees required to operate and maintain a 15-acre geothermal direct use enterprise park.

Capital and O&M costs were further separated into two groups: geothermal costs and non-geothermal costs. Geothermal costs relate to the geothermal system itself (heat exchanger, pumps, piping, valves, controls, and equipment building) and also include insurance and geothermal system electricity. Non-geothermal costs relate to the site development and include: roadway, utilities, property taxes and property management fees. See Table 6-1 for a summary of estimated costs.

ECONOMIC ANALYSIS
TABLE 6-1: ESTIMATED COST SUMMARY

Cost Descriptions	Dollars
Non-Geothermal Capital Costs (See Table E-1)	$6.52 million*
Geothermal Capital Costs (See Table E-2)	$5.99 million*
Annual Non-Geothermal O&M Costs (See Table 6-2)	$490
Annual Geothermal O&M Costs (See Table 6-3)	$737,400

*The capital costs are based on a 15-acre geothermal direct use enterprise park subdivided into thirteen 1-acre lots. One lot is reserved for above ground geothermal system equipment such as pumps, piping, valves, and buildings. It was therefore reasoned that one thirteenth of the subdivision capital costs, or $543,000, should be removed from the non-geothermal capital costs and added to the geothermal capital costs. The estimated capital costs in Table 6-1 reflect this adjustment.

ECONOMIC ANALYSIS
TABLE 6-2: ANNUAL NON-GEOTHERMAL O&M COSTS

Cost Descriptions	Dollars
Property Tax (Estimated)[1]	$250
Property Management Fees (10% of Lease Rate+Taxes)[2]	$240
Annual Non-Geothermal O & M Costs	**$490**

[1]Property tax based on current Hawaii County tax rates for agricultural class property at a rate of $8.35 per $1,000 dollars of land and building value. It was assumed that the County will own all on-site roadways and utilities and they were not included in the estimated property tax. Estimated value of the enterprise park excluding tenant improvements is 30,000 for land value. Total estimated property tax based on $30,000 is $250.

[2]Lease rate is based on $200/acre-year (Hopkins, M. 2007), 12 acres, for a grand total of $2,400 per year.

ECONOMIC ANALYSIS
TABLE 6-3: ANNUAL GEOTHERMAL O&M COSTS[1]

Cost Descriptions	Dollars
Geothermal System Management Fees (Estimated)[2]	$150,000
Maintenance Costs (2% of Geothermal Cap. Costs)	$118,800
Preventive Maint. Costs (2% of Geothermal Cap. Costs)[3]	$118,800
On-Site Operator (8-Hour Shifts, $75/hour, $156,000/yr)	$156,000
Operator On-Call Emergency Overtime Allowance (20% of Wages and Benefits)	$31,200
Insurance to High Temperature Geothermal Application Business (1% of Geothermal Cap. Costs)[4]	$59,400
Lease Rate ($200/acre-year, 1 acre, $200 total/yr)	$200
Property Tax (Estimated)[5]	$50,000
Pump Electricity (See Appendix E for Calculations)	$53,000
Annual Geothermal O & M Costs	**$737,400**

[1]It was assumed that geothermal heat would be free and the State of Hawaii would not charge for geothermal royalties. Royalties are valued at $225,000 based on 10% of the heat value of 6.6 million Btu. For estimation purposes, the value of propane and diesel were used as benchmarks: 84,300 Btu heat content per gallon of propane, $2.20 per gallon of propane (Daimaru 2006); 129,500 Btu heat content per gallon of diesel, $3.47 per gallon of diesel.

[2]Geothermal system management fees are composed of park management fees, public relations fees, legal fees, and accounting fees.

[3]Preventive maintenance fees would be collected to pay for future maintenance costs including periodic painting, equipment replacement, and upgrades. It was assumed that money received for preventive maintenance would be invested in a guaranteed interest account to preserve its value.

[4]The purpose of the insurance would be to cover possible damage that that the high temperature geothermal application equipment could incur by operating the geothermal direct use system. Actual coverage requirements and premiums are unknown and a premium equivalent to 1% of the geothermal direct use system was assumed.

[5]Property tax based on current Hawaii County tax rates for agricultural class property at a rate of $8.35 per $1,000 dollars of land and building value. It was assumed that the County will own all on-site roadways and utilities and they were not included in the estimated property tax. Estimated value of the geothermal system is $5.99 million. Total estimated property tax based on $5.99 million is $50,000.

6.3 GEOTHERMAL ENTERPRISE PARK REVENUE

Lease and heat energy fees are two possible sources of revenue for a geothermal direct use enterprise park. Lease fees would be charged for the use of land in the geothermal direct use enterprise park. Heat energy fees would be charged for the use of geothermal heat.

Lease revenue is dependent on the rate charged for land and should be comparable to the prevailing lease rates in the Kapoho / Pohoiki area. Most of the land in the geothermal resource subzones is zoned agricultural according to State of Hawaii Land Use Maps and it was therefore determined that agriculture lease rates would be appropriate for a geothermal direct use enterprise park. Current annual agriculture lease rates in the Kapoho / Pohoiki area are estimated to be $200 per acre (Hopkins, M. 2007). Estimated annual lease revenue for a 15-acre geothermal direct use enterprise park, with twelve 1-acre parcels available for lease at a rate of $200 per acre-year, is $2,400.

Annual geothermal heat revenue is dependent on the rate charged per unit of geothermal heat delivered to enterprise park tenants. Higher rates are more attractive for private developers / investors but less appealing for geothermal direct use enterprise businesses. Conversely, lower rates are more appealing for geothermal direct use enterprise businesses but less attractive for private developers / investors. It was reasoned that the maximum rate that could be charged for geothermal heat would be the rate charged for an equivalent amount of fossil fuel generated heat. An average heat consumption rate, estimated in Chapter 5 – Engineering Cost Analysis, of 6.6 million Btu per hour is worth approximately $2.4 million in propane or $2.45 million in diesel per year assuming a 63% water heating efficiency. A heat content of 84,300 Btu per gallon at a cost of $2.20 per gallon (Daimaru 2007) was used for propane. A heat content of 129,500 Btu per gallon at a cost of $3.47 per gallon was used for diesel. The average of both rates is $2.64 per therm, which was used as the basis for the maximum rate that could be charged for geothermal heat. Estimated annual heat energy revenue for a 15-acre geothermal direct use enterprise park consuming an average of 6.6 million Btu per hour at a cost rate of $2.64 per therm is $2.42 million. In reality, the maximum chargeable rate would be somewhat lower than $2.64 per therm to provide an incentive for potential geothermal direct use businesses to use geothermal heat in lieu of fossil fuel generated heat.

6.4 ECONOMIC FEASIBILITY ANALYSIS OF THE GEOTHERMAL SYSTEM

The economic feasibility analysis focused on the hypothetical 15-acre geothermal direct use enterprise park and did not consider the economic feasibility of individual prospective geothermal direct use businesses. Each prospective geothermal direct use enterprise will be affected by factors and circumstances unique to each business and experts should be consulted on a case-by-case basis.

6.4.1 Economic Feasibility Defined

There are many factors that affect the economic feasibility of a geothermal direct use enterprise park in the Kapoho / Pohoiki area, including the cost of geothermal heat (fees to the "owner" of the heat source and any royalties to the State of Hawaii), cost of electricity, cost of oil, cost of geothermal heat, available subsidies (grants, tax incentives, and shared development costs), and acceptable rates of return. In order to determine the economic feasibility of a 15-acre geothermal direct use enterprise park, two extreme economic scenarios were analyzed.

On one extreme, economic feasibility was defined as the ability to deliver heat energy at a reasonable rate to geothermal direct use customers, provide an attractive rate of return for private investors, and provide sufficient funding to maintain the ability to indefinitely sustain system operations. The geothermal direct use enterprise park would need to generate enough revenue to pay for all of the capital costs, O&M costs, and investment returns. It was assumed that no financial subsidies are provided and private investors will provide all the necessary funding under this economic feasibility scenario.

On the other extreme, economic feasibility was defined as the ability to deliver heat energy at a reasonable rate to geothermal direct use customers while maintaining the ability to indefinitely sustain system operations. The geothermal direct use enterprise park would need to generate enough revenue to pay for O&M costs only. It was assumed that significant subsidies are provided to pay for capital costs and that private investors provide no funding under this economic feasibility scenario.

The economic feasibility analysis of a 15-acre geothermal direct use enterprise park was divided into three separate analyses. One analysis considered the feasibility of a non-geothermal agricultural enterprise park located in the Kapoho / Pohoiki area. A second analysis considered the feasibility of a geothermal direct use system for a 15-acre enterprise park. The third analysis considered the feasibility of a 15-acre geothermal direct use enterprise park located in the Kapoho / Pohoiki area.

6.4.2 Economic Feasibility of an Agricultural Enterprise Park

The economic feasibility of an agricultural enterprise park is dependent on non-geothermal related costs and revenue. The capital cost to plan, design, and construct a 15-acre non-geothermal agricultural enterprise park in the Kapoho / Pohoiki area is estimated to be approximately $6.52 million. The revenue from leases is expected to be approximately $2,400 per year. Assuming that tenants will be responsible for property taxes on improvements they make, and a lease property manager will charge 10% of the lease rate, 90% of the lease revenue or $1,910 will be available as annual income. The payback period for a non-geothermal related capital investment of $6.52 million, at a net income rate of $1,910, is 3,414 years. A payback period of

3,414 years is not attractive and it was concluded that a 15-acre agricultural enterprise park is not economically feasible in the Kapoho / Pohoiki area with leases as the only source of revenue. A 15-acre agricultural enterprise park could become feasible if significant financial subsidies are provided, or if geothermal heat revenue can cover non-geothermal related capital costs.

6.4.3 Economic Feasibility of Geothermal System

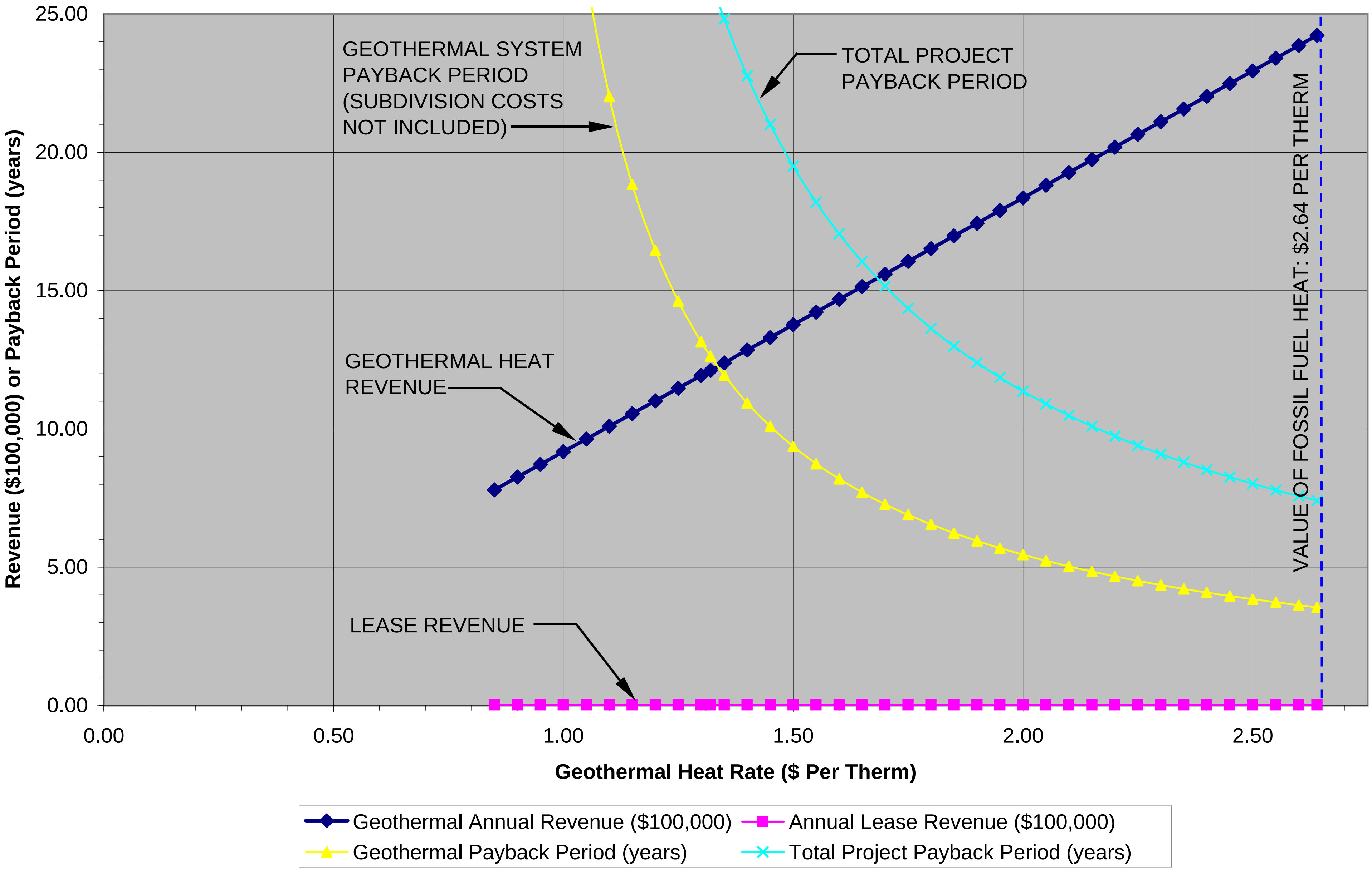
The economic feasibility of a geothermal system is dependent on geothermal related costs and revenue. The capital cost to plan, design, and construct a geothermal system to supply heat to a 15-acre agricultural enterprise park located in the Kapoho / Pohoiki area is estimated to be approximately $5.99 million. The O&M cost to operate and maintain the geothermal system is estimated to be approximately $737,000. The maximum revenue from geothermal heat supplied to tenants is expected to be between approximately $737,000 and $2.42 million. The lower the geothermal heat rate charged to tenants, the more attractive geothermal direct use becomes. Clearly there is a balance that must be struck between geothermal system economic interests and direct use enterprise economic interests. A minimum annual revenue of $737,000 was selected because it is equivalent to the estimated annual O&M costs for the geothermal system. A maximum annual revenue of $2.42 million was selected because it is equivalent to the annual estimated cost of using fossil fuel generated heat. Charging the maximum rate of $2.64 per therm of geothermal heat would generate approximately $1.69 million of net income. The payback period for an initial geothermal related capital investment of $5.99 million at a net income rate of $1.69 million is 3.5 years. The payback period at a 25% discount rate of $1.98 per therm and an annual net income rate of $1.08 million is 5.5 years. The payback period at a 50% discount rate of $1.32 per therm and an annual net income rate of $0.47 million is 13 years. It was concluded that a geothermal system for a 15-acre enterprise park located in the Kapoho / Pohoiki area is at best marginally economically feasible based on a payback period of 13 years and a discounted heat rate of 50%.

6.4.4 Economic Feasibility of a Geothermal Direct Use Enterprise Park

The economic feasibility of a geothermal direct use enterprise park is dependent on geothermal and non-geothermal related costs and revenue. The capital cost to plan, design, and construct a 15-acre geothermal direct use enterprise park in the Kapoho / Pohoiki area is estimated to be approximately $12.5 million. The O&M cost to operate and maintain the 15-acre geothermal direct use enterprise park is estimated to be approximately $738,000. The maximum revenue is expected to be between approximately $738,000 and $2.42 million. The payback period at a 50% discount heat rate of $1.32 per therm and an annual net income rate of $0.47 million is 26 years. See Chart 6-1 and Table 6-4 for other geothermal heat rates and payback periods. It was concluded that a 15-acre geothermal direct use enterprise park is not economically feasible in the Kapoho / Pohoiki area based on a payback period of 26 years. A 15-acre geothermal direct use enterprise park could become feasible if significant financial subsidies are provided to reduce the payback period and if favorable conditions occur. For example, the payback period could be reduced to 7 years, if $9.2 million in financial subsidies are provided. Also, the following favorable conditions were assumed and could have an impact on the economic feasibility analysis if they do not occur:

- Substantial subsidies are provided to finance the bulk of the site development and infrastructure costs.
- Geothermal “waste” heat is available free of charge from a high temperature geothermal application business. It was assumed that the high temperature geothermal application business would have no other use for the waste heat, and would be willing to supply the heat at no cost.

ENGINEERING COST ANALYSIS
CHART 6-1: PAYBACK PERIOD



ENGINEERING COST ANALYSIS
TABLE 6-4: PAYBACK PERIOD

Geothermal Heat Rate ($/therm)	Geothermal Annual Revenue ($100,000)	Annual Lease Revenue ($100,000)	Geothermal Payback Period (years)	Total Project Payback Period (years)
0.85	7.80	0.024	140.4	280.5
0.90	8.26	0.024	67.7	138.2
0.95	8.72	0.024	44.6	91.7
1.00	9.18	0.024	33.2	68.6
1.05	9.64	0.024	26.5	54.8
1.10	10.09	0.024	22.0	45.6
1.15	10.55	0.024	18.8	39.1
1.20	11.01	0.024	16.5	34.2
1.25	11.47	0.024	14.6	30.4
1.30	11.93	0.024	13.1	27.3
1.32	12.11	0.024	12.6	26.3
1.35	12.39	0.024	11.9	24.8
1.40	12.85	0.024	10.9	22.8
1.45	13.31	0.024	10.1	21.0
1.50	13.77	0.024	9.4	19.5
1.55	14.22	0.024	8.7	18.2
1.60	14.68	0.024	8.2	17.1
1.65	15.14	0.024	7.7	16.1
1.70	15.60	0.024	7.3	15.2
1.75	16.06	0.024	6.9	14.4
1.80	16.52	0.024	6.6	13.6
1.85	16.98	0.024	6.2	13.0
1.90	17.44	0.024	6.0	12.4
1.95	17.90	0.024	5.7	11.9
2.00	18.35	0.024	5.5	11.4
2.05	18.81	0.024	5.2	10.9
2.10	19.27	0.024	5.0	10.5
2.15	19.73	0.024	4.8	10.1
2.20	20.19	0.024	4.7	9.7
2.25	20.65	0.024	4.5	9.4
2.30	21.11	0.024	4.4	9.1
2.35	21.57	0.024	4.2	8.8
2.40	22.03	0.024	4.1	8.5
2.45	22.48	0.024	4.0	8.3
2.50	22.94	0.024	3.8	8.0
2.55	23.40	0.024	3.7	7.8
2.60	23.86	0.024	3.6	7.6
2.64	24.23	0.024	3.6	7.4

Given:

Non-Geothermal Capital Costs = $6.52 million
Non-Geothermal O&M Costs = $490
Geothermal Capital Costs = $5.99 million
Geothermal O&M Costs = $737,400
Average Enterprise Park Heat Consumption = 6.6 million Btu/hr
Average Water Heating Efficiency = 63%

Sample Calculations:

Calculate Geothermal Annual Revenue:

Geothermal Annual Revenue = qnT/*n*

Where: q = heat consumption rate (Btu/hr)
n = geothermal heat rate ($/therm)
T = time period (years)
n = heating efficiency

Geothermal Annual Revenue = ($6.6x10^6$ Btu/hr)($1.32/therm)(1 year)(365 days/yr)(24 hours/day)/(0.63)
= $1.21 million

Calculate Geothermal Payback Period:

$T_{geothermal}$ = (Geothermal Capital Costs)/(Annual Geothermal Revenue - Geothermal O&M Costs)

Where: $T_{geothermal}$ = Payback Period for Geothermal Costs (years)

$T_{geothermal}$ = ($5.99 million per year)/($1,210,000-$737,400) = 13 years

Calculate Total Project Payback:

$T_{total\ project}$ = (Geothermal Capital Costs + Non-Geothermal Capital Costs)
/(Annual Geothermal Revenue + Annual Lease Revenue - Geothermal O&M Costs)

Where: $T_{total\ project}$ = Payback Period for Total Project Costs (years)

$T_{total\ project}$ = ($12.5 million per year)/($1,210,000+$2,400-$737,890) = 26 years

- The high temperature geothermal application business that will provide the free “waste” heat for geothermal direct use will remain in business in the same location for a long period of time. This assumption could be affected by factors such as geothermal heat production rates. Geothermal heat production rates in terms of steam/water ratio, temperatures, and chemical constituents of deep geothermal fluid can change over time. Management of well operations can also affect geothermal heat production rates (Thomas 2007).
- Geothermal direct use businesses will not be charged royalties by the State of Hawaii. It was assumed that the State of Hawaii would either exempt geothermal direct use from royalties, or provide a temporary waiver until geothermal direct use enterprises were successfully developed. See Chapter 4 – State and County Regulatory Improvements to Encourage the Direct Use of Geothermal Heat for proposed changes to Hawaii State statutes.
- Cost of fossil fuel derived energy will not increase. It was assumed that the cost of conventional fossil fuels would remain the same. In reality, the feasibility of geothermal heat would increase as the cost of conventional fuel energy increases, and decrease as the cost of conventional fuel energy decreases.
- Geothermal direct use businesses will pay for any on-site construction costs necessary to operate their respective businesses.
- The geothermal direct use enterprise park will be located near roads and utilities. It was assumed that the enterprise park would be located adjacent to a high temperature geothermal application business. It was also assumed that the high temperature geothermal application business would pay for any roadway and utility extensions necessary to service its operation and, therefore, the surrounding area.
- The geothermal direct use enterprise park will be 100% occupied. This assumption was made to determine the minimum required geothermal heat rate to allow economic feasibility.

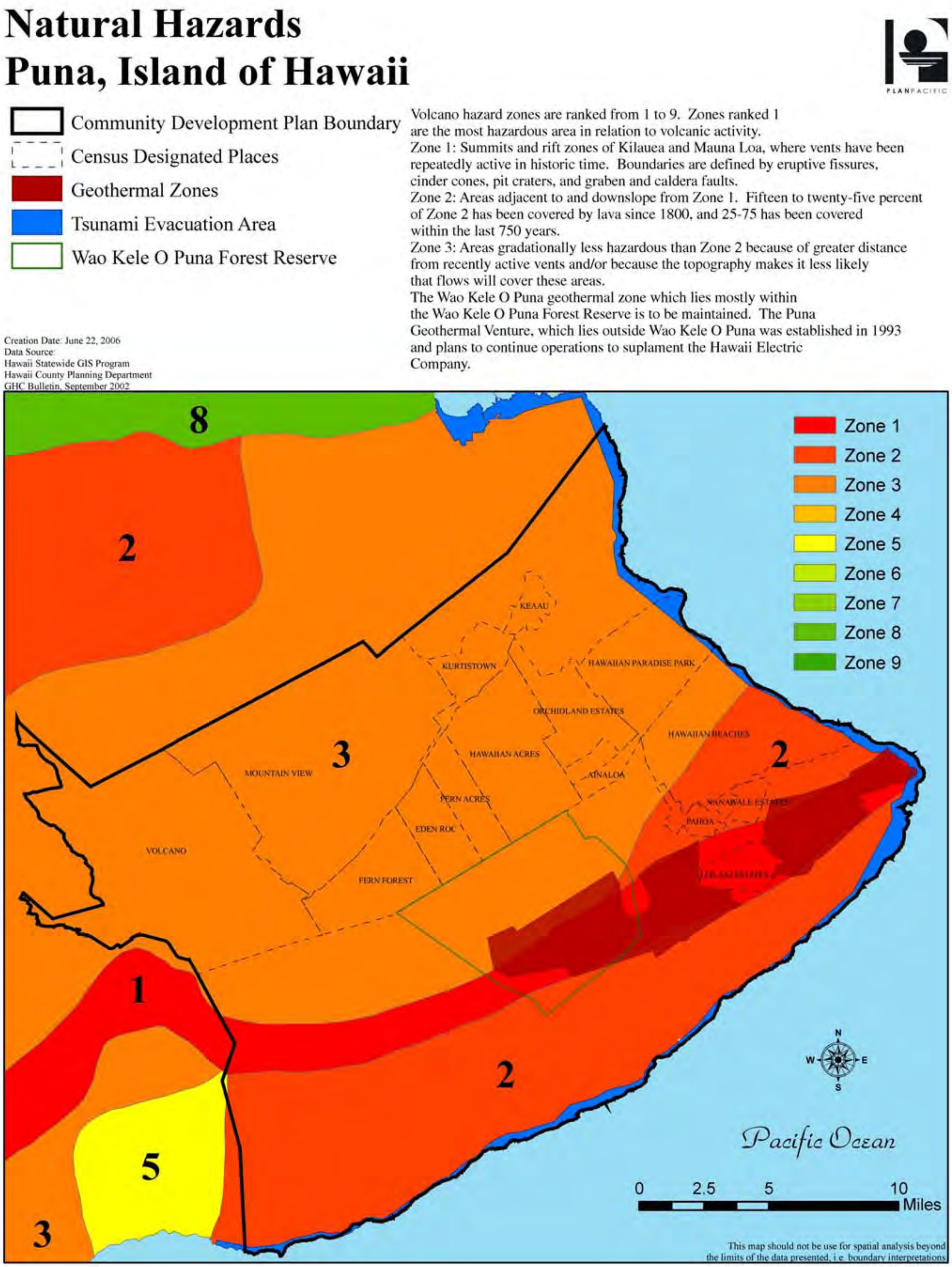
- Geothermal direct use entrepreneurs will accept the risks associated with locating a business in a high natural hazard area. The Kapoho / Pohoiki area is located in a high natural hazard zone which is likely to have a negative impact on the insurability of businesses. See Figure 6-1 for hazard zones in the Kapoho / Pohoiki area.
- The 15-acre geothermal direct use enterprise park will be expandable. It is hoped that future enterprise park expansion and increased heat consumption will improve direct use economics through economies of scale.

6.5 SUMMARY OF ENGINEERING COST ANALYSIS

A geothermal direct use enterprise park requires significant capital for infrastructure development and construction such as roads, water piping and power lines. It also requires significant capital for equipment such as buildings, heat exchangers, pipes, pumps, insulation, and controls. Non-geothermal related capital and O&M costs are estimated to be $6.52 million and $490 respectively. Geothermal related capital and O&M costs are estimated to be $5.99 million and $737,000 respectively. Estimated annual revenue from leases is $2,400; estimated annual revenue from geothermal heat is $1.21 million based on a geothermal heat rate priced at $1.32 per therm, which is a 50% discount of the prevailing average fuel rate of diesel and propane.

The value of the geothermal heat delivered annually is estimated to be $2.42 million. The difference between the value of the heat delivered and geothermal related O&M costs, $1.68 million, is the amount of money available to pay for geothermal capital costs and to offer as heat energy discounts to attract businesses to become tenants of the geothermal direct use enterprise park. Based on the projected energy cost savings, it appears a geothermal direct use enterprise park in the Kapoho / Pohoiki area would require significant subsidies before it could become feasible. The payback

ENGINEERING COST ANALYSIS
FIGURE 6-1: NATURAL HAZARDS



period could be reduced to 7 years if $9.2 million in financial subsidies are provided.

In conclusion, a geothermal direct use enterprise park is marginally economically feasible at best, provided that sufficient subsidies are provided to underwrite the majority of the capital costs, and a number of assumed favorable conditions occur.

CHAPTER 7 – ECONOMIC IMPACT AND PROMOTIONAL PLAN

7.1 INTRODUCTION

In this chapter, the economic benefits associated with each direct use enterprise are estimated and presented, measured in part by reducing dependence on imported oil. The direct use enterprises with the greatest potential are identified in Chapter 2, Table 2-1: greenhouse bottom heating, lumber kiln, sterilization/pasteurization of potting media, conversion of used oils into biodiesel fuel, and a university/research facility. Each is analyzed for its potential to generate economic activity measured by expected value of sales per $1000 in assets. That information is then used to estimate the additional (or multiplied) output, earnings, total employment, and state taxes. This gives decision-makers additional information that bears upon the economic viability of the project.

For example, at levels of asset investment of $500,000 per identified industry, $9.2 million in additional sales, 130 new jobs, and $380,000 in additional taxes would be generated. Further, these activities using geothermal heat at these operating scales would save approximately 8000 avoided barrels of crude oil per year.

7.2 SUBSTITUTING GEOTHERMAL ENERGY FOR OIL

As is well known, approximately 75% of electricity generated on the Big Island is derived from imported oil.[1] The benefits of direct use of the geothermal resource associated with reducing reliance on imported oil are estimated in this section using avoided-barrels of crude oil as a measure of the benefits. An ‘avoided-barrel’ is defined as a barrel of crude oil that alternative energy usage (e.g. geothermal) replaces. This quantity depends on the available

[1] Accessed 1/21/07 see:
http://www.oilcrisis.com/Zagar/hawaii/ and
http://hawaiiislandjournal.com/2005/05b05b.html

enterprises that may be able to use the geothermal source and the scale of their operation.

7.2.1 Avoided Barrel and Avoided Gas Emission Estimates

As noted above, the direct use enterprises with development potential are identified in Chapter 2, Table 2-1, as greenhouse bottom heating, lumber kiln, sterilization/pasteurization of potting media, conversion of used oils into biodiesel fuel, and a university/research facility. Illustrative cases for greenhouse bottom heating and lumber kilns are used as examples of how to calculate the barrels of avoided-crude oil if geothermal heat were to be used.

Greenhouse bottom heating can speed the growth cycle of certain plants, e.g. orchids, and allow for more controlled growth and higher output. Greenhouse operators using bottom-heating may use diesel oil-fired boilers to heat water which circulates through piping below the actual growing tables, raising the ambient air temperature to the desired level.

Technically, crude oil can be transformed into diesel fuel with 86% efficiency.[2] This means that every barrel of diesel oil avoided leads to 1.163 avoided barrels of crude oil. Depending on how much extra heat needs to be provided, estimates for avoided-barrels of crude oil follow.[3] At current (January 2007) prices of diesel oil of $3.47/gallon, every $1000 per month spent on diesel oil is equivalent to 6.86 barrels of diesel oil and 7.98 avoided-barrels of crude oil.[4]

[2] See: http://www.cffs.uky.edu/C1/2003%20meeting/Review%20Motal.pdf. Accessed 1/24/07.

[3] Measuring net avoided-barrels also depends on assuming that all other growing conditions are identical. This may not be the precise case in agriculture, as activity taken at one elevation may require a different amount of added heat (thus fuel) than the same activity undertaken at a different elevation (e.g. the proposed Geothermal Enterprise Park). However, the following estimates are illustrative.

[4] Forty-two gallons per US barrel, and the price of diesel oil from http://www.fuelgaugereport.com/sbsavg.asp, accessed 1/21/07.

Over a year, this is 95.74 avoided barrels of crude oil. Clearly, the larger the enterprise, the greater the number of avoided-barrels will be.

The same avoided barrels conversion factor holds for other identified users if the information is available in similar (dollars-spent-on-fossil-fuel) form. However, sometimes information or estimates are available only in "dollars-spent-on-electricity" form. This complicates the avoided-barrel computation, as electricity charges include all costs of generation, not just fuel charges.

For example, Tenon Manufacturing Ltd. In New Zealand is estimated to be saving $(US) 1,000,000 per year on electricity charges in its nine kilns in the Taupo region.[5] Using this information an "average" savings in electricity costs of per kiln of $111,111 is derived.

At the current rate of approximately $0.25 per kWh on the Big Island for "medium" power use businesses[6], this translates into approximately 444,444 kWh which (at 501 net kWh/barrel) requires 888 barrels of diesel oil to generate.[7]

If $1000 does not need to be spent on electricity, 4,000 kWh of electricity or 8 barrels of residual or diesel fuel are saved (at current prices).

Using the factor of 1.163 barrels of crude oil per barrel of diesel oil, each $1000 spent on electricity leads to 9.3 avoided barrels of crude oil. Each avoided barrel of crude oil reduces the need to ship oil into the islands, and

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[5] http://www.scoop.co.nz/stories/BU0608/S00439.htm

[6] See http://www.heco.com/portal/site/heco/menuitem.8e4610c1e23714340b4c0610c510b1ca/?vgnextoid=8589f2b154da9010VgnVCM10000053011bacRCRD&vgnextfmt=default, accessed 1/21/07

[7] See http://www.entech.co.uk/entech/ener_conv.htm or http://www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html. There are approximately 1700 kWh of electricity in a barrel of fuel oil, however, power plants are, on average, 31% efficient and an additional 5% of that energy is lost in transmission from source to user. Thus, 1700*0.31*0.95 = 501 net kWh per barrel. Power plant efficiency information from Mr. Robert Arrigoni, County of Hawaii, private communication, February 7, 2007.

also reduces the greenhouse gas emissions which would result from combustion. Given that one barrel of oil is equivalent to 501 kWh of electricity, for every avoided barrel of crude oil 0.43 tons of carbon dioxide are kept from being released into the environment.[8]

Thus, for every $1000 of electricity expenditures that can be replaced by geothermal resources, 9.3 barrels of crude oil are avoided; and the release of 4.0 tons of carbon dioxide gas emissions (or the cost of abating them) are avoided).[9]

7.2.2 Scale of Operation

The information provided in this report allows decision-makers to calculate avoided barrels of crude oil and avoided emissions whether data given them is in costs of fuel or costs of electricity (given current Hawaii prices).[10]

TABLE 7-1: AVOIDED BARRELS OF CRUDE OIL AND AVOIDED CO_2 EMISSIONS[11]

	$1,000 Expenditure on Diesel Fuel	$1,000 Expenditure on Electricity (HELCO)
Avoided Barrels of Oil	6.86	9.3
Avoided CO_2 Emissions (tons)	2.94	4.0

[8] See: http://www.seen.org/pages/db/method.shtml Accessed 1/21/07.

[9] This assumes that there is no carbon dioxide consequence of the geothermal resource.

[10] The impact on the state's balance of trade of avoided barrels would be a matter of scale. Suppose that there were two users, one who would have purchased $100,000 worth of diesel oil per year and the other purchasing $100,000 of electricity from HELCO (both at current prices). Then 798+930 = 1,728 barrels of crude oil are avoided annually. In 1999, Hawai`i imported about 140,000 barrels of oil per day.

[11] Diesel oil at $3.47/gallon = $145.74/barrel; electricity at $0.25/kWh. Obviously, any enterprise, such as biodiesel, that produces a substitute for imported oil could be credited directly for avoided-barrels by just including its output of biodiesel in barrels in the total.

7.3 ECONOMIC ACTIVITY ASSOCIATED WITH IDENTIFIED ENTERPRISES

In addition to the oil savings outlined above, each identified industry/enterprise is also expected to generate measurable economic activity created by gross sales. Forecasting the direct and indirect economic impact of any enterprise depends on the level of activity undertaken and the follow-on, or multiplier effects associated with that type of activity.

7.3.1 The Level of Economic Activity Associated with Identified Enterprises

Each identified enterprise—greenhouse bottom heating, lumber kiln, sterilization/pasteurization of potting media, conversion of used oils into biodiesel fuel, and a university/research facility—can be analyzed at various levels of economic activity using information from Risk Management Associates, Annual Statement Studies, 2004-2005.

The Risk Management Association (RMA) reports current and historical financial statement data by industry. The data for these studies include an analysis of a number of firms in each industry. The number of firms in the sample varies by industry, in this case ranging from 38 to 564. RMA aggregates these data by the size of the firm based on the firm's sales and assets levels. In addition, RMA provides historical data based on the average of all firms without regard to firm size. Because the size of the operations undertaken in a geothermal enterprise park may vary, perhaps starting small and then potentially growing, the historical data were used.[12]

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[12] See Appendix F for more information on RMA and some of the calculations underlying the following assets-to-sales estimates for the identified industries.

As in any industry, there will be a continuum of entrepreneurial abilities; some management—given the same resources and chances—will out-perform others. Aggregate, national data give us the best picture of how 'average' management performs in an industry.

It may be that the innovation and enterprise associated with trying 'new things', such as participation in a geothermal park might represent, attracts (or self-selects) those with a special set of entrepreneurial/management skills. If that is the case, the national averages may be indicative of what might be expected, but may under-predict performance.

Mitigating this effect is the likelihood that the national averages may yield higher sales-asset ratios for businesses on isolated islands (e.g. the Big Island). This could happen for at least two reasons, first, sales may be lower per dollar of assets due to higher costs (e.g. costs associated with transportation, The RMA data allow this part of the study to begin by associating a level of annual gross sales per $1,000 of assets invested for the average firm in the industry. As a result, without needing to lock-in any particular participant's size of enterprise, a range of sales (output) estimates are provided based on five levels of economic investment: $50,000, $100,000, $250,000, $500,000, and $1,000,000.

7.3.2 Lumber Kiln

An analysis of a lumber kiln is based on RMA data (Table F-3) indicating $7,692 in gross sales for every $3,077 of assets (or $2.50 in gross sales per dollar of assets). Table 7-2 shows the level of gross sales (final demand) associated with each identified level of asset size in lumber kilns[13]:

TABLE 7-2: LUMBER KILN

Dollar Amount of Assets	Sales
$50,000	$125,000
$100,000	$250,000
$250,000	$625,000
$500,000	$1,250,000
$1,000,000	$2,500,000

7.3.3 Greenhouse Bottom Heating

Based on RMA data of $5,574 in gross sales for every $3,279 of assets, a figure of $1.70 in gross sales for every $1 in assets is used for the

inputs, information) and, second, required assets may be higher in order to generate a given dollar value of sales.

[13] Lumber kilns using a geothermal source operate successfully elsewhere, e.g. see: http://www.nzbcsd.org.nz/story.asp?id=719.There are two columns showing gross sales for kilns in Table F-3, in this case (and the cases that follow), where multiple values are available, unless otherwise indicated, we choose the smaller (or smallest) value of gross sales per $1000 of assets.

greenhouse analysis. Table 7-3 shows the level of gross sales (final demand) associated with each identified level of assets in greenhouses[14]:

TABLE 7-3: GREENHOUSES

Dollar Amount of Assets	Sales
$50,000	$85,000
$100,000	$170,000
$250,000	$425,000
$500,000	$850,000
$1,000,000	$1,700,000

7.3.4 Sterilizing Potting Media

Based on RMA data of $8,696 in gross sales for every $4,831 of assets ($1.80-to-$1.00), Table 7-4 shows the level of gross sales (final demand) associated with each identified level of asset investment in sterilizing potting media[15]:

TABLE 7-4: POTTING MEDIA

Dollar Amount of Assets	Sales
$50,000	$90,000
$100,000	$180,000
$250,000	$450,000
$500,000	$900,000
$1,000,000	$1,800,000

[14] Conversations with those knowledgeable about floriculture on the Big Island indicate that this nationally derived ratio of $1.70 sales -to-$1.00 assets might be overstated. Estimates for the Big Island may be closer to $1-to-$1 or even a bit lower than that.

[15] Consistent with Chapter 2, conversations held with those in the industry indicate the economic imperative to supply used potting media for sterilization seemed lacking at this time. In short, currently there are alternative in-house uses for used potting media that out-compete sterilization. Of course, this decision would depend on prices paid for new and used potting media and may change through time.

7.3.5 Processing Used Food Oils Into Biodiesel Fuels

Based on RMA data of $5,740 in gross sales for every $3,021 of assets ($1.90-to-$1.00), Table 7-5 shows the level of gross sales (final demand) associated with each identified level of asset investment in biodiesel production:

TABLE 7-5: BIODIESEL

Dollar Amount of Assets	Sales
$50,000	$95,000
$100,000	$190,000
$250,000	$475,000
$500,000	$950,000
$1,000,000	$1,900,000

7.3.6 A University-Sponsored Research and Development Facility

Based on RMA data of $2,754 in gross sales for every $2,019 of asset investment ($1.364-to-$1.00), Table 7-6 shows the level of gross sales (final demand) associated with each identified level of asset investment in a research facility[16]:

[16] The figure of $2,754 per $2,019 of assets is derived from the average of gross sales in a research center ($4,651) and a university ($856) and assets in each (see Table F-3).

While the 'narrow' economic benefits of a research park are calculated, the obvious non-economic benefits may include the development of new and beneficial technologies based on the use of the geothermal resource; a 'demonstration' benefit of show-casing feasible uses; and a management benefit of providing a 'champion' for the use of the resource and possible assistance in managing the park.

Table 7-6: RESEARCH FACILITY

Dollar Amount of Equity Investment	Sales
$50,000	$68,200
$100,000	$136,400
$250,000	$341,000
$500,000	$682,000
$1,000,000	$1,364,000

7.3.7 Community Center

A community center has been proposed as a candidate of a geothermal enterprise park. The community center is not expected to generate revenue. The exact cost of the project would vary by construction style. Based on figures derived from Reed Construction Data, Construction Cost Estimator and private conversations with industry representatives for the construction of a Community Center in Pahoa, Hawaii, we estimate the final construction cost will range between $225 to $300 per square foot. Thus, a 3,000 square foot building would cost $675,000 to $900,000[17]. The higher estimated costs are selected to allow for the inclusion of specialized equipment including a kitchen, fruit dryer, fish dryer and other items that may be deemed desirable.

7.3.8 Economic Multiplier Effects Given Levels of Activity

The use of economic multipliers to analyze changes in output, earnings, employment, and taxes stimulated by changes in a particular sector or industry are becoming increasingly well known. Assisting such analyses is the production of national, regional, and state input-output tables that provide a snapshot of the interrelationships among sectors of the economy. In Hawaii,

[17] Source: Estimated using the Reed Construction Data, Construction Cost Estimator www.reedfirstsource.com accessed 1-10-07. Estimates were for the cost of a 3,000 square foot community center, constructed in Pahoa, Hawaii. The mean value was about $216/ft.sq. However, this range more properly reflects current conditions.

the State's Department of Business, Economic Development and Tourism produces this information[18]

Changes in output within any sector or industry have multiplier effects on the entire economy. 'Up-stream' and 'down-stream' industries are affected, as the changes in one sector affect the output and employment required from other sectors. In addition, those changes induce further effects on output and employment in still other sectors of the economy. In the same way, changes in output create changes in earnings, which create induced effects as well. These effects on output, employment, and earnings create changes in the expected tax revenues for the state government. Input-output (I-O) multipliers capture both direct and induced effects allowing the determination of the economy-wide impacts of a project.

In Table 7-7 reports the final-demand, Type II multipliers from the detailed tables of the State's 2002 I-O study, with the employment multipliers up-dated to their expected 2007 values. These multipliers capture the direct and induced effects of changes in one sector cascading/multiplying through the economy onto other sectors.

[18] See:http://www.hawaii.gov/dbedt/info/economic/data_reports/2002_state_io/ .

TABLE 7-7: STATE OF HAWAII FINAL DEMAND TYPE II MULTIPLIERS

	Output	Earnings	Employment (total jobs)	State Tax (dollars)
Greenhouse, Potting media	2.05	0.67	38.84	0.08
Lumber Kiln	2.06	0.80	33.02	0.10
Biodiesel	1.84	0.55	13.96	0.06
Univ/Res. Park	1.96	0.67	15.23	0.09

Source: http://www.hawaii.gov/dbedt/info/economic/data_reports/2002_state_io/
See: 2002 State Input-Output Tables - Detailed. Industry 5—Flowers and Nursery Products—is used for greenhouses and potting media; Industry 11—Support Activities for Agriculture—for lumber kilns; Industry 21—Other Manufacturing—for biodiesel; and Industry 47—Research and Development in the Physical, Engineering, and the Life Sciences—is used for the university research facility.

Each entry in the final-demand output multiplier column shows the total dollar change in output in all industries that results from a $1 change in final demand (i.e. sales) in the corresponding industry. So, for example, if there is a $1 increase in sales in greenhouse flowers, sales in all industries (including the initial $1 in flowers) rise by $2.05 from the direct and indirect effects outlined above.

Each entry in the earnings multiplier column shows the total change in earnings received by households from all industries that results from a $1 change in final demand (sales) in the corresponding industry. So, for example, if there is a $1 increase in sales in greenhouse flowers, earnings by households employed in all industries rise by $0.67 from the direct and indirect effects outlined above.

Each entry in the final-demand employment multiplier column shows the total change in number of jobs in all industries that results from a $1 million change in final demand in the corresponding row industry. For example, if there is a $1M increase in sales of greenhouse flowers, then employment in all industries rises by approximately 39 jobs due to the direct and indirect effects outlined above.

Finally, each entry in the final-demand state tax multiplier column shows the total change in state tax revenues from households and all row industries that results from a $1 change in final demand in the corresponding row industry. So, for example, if there is a $1 increase in sales in greenhouse flowers, state tax revenues increase by $0.08 from the direct and indirect effects outlined above.

7.4 ECONOMIC IMPACT OF IDENTIFIED INDUSTRIES

Combining the two elements of section 7.3—the increased level of activity with the multiplier impact of that activity—allows us to make estimates of the ultimate economic activity that may be generated by investment in the identified industries for the geothermal enterprise park.

The gross sales figures from Tables 7-2 through 7-6 and the multipliers from Table 7-7 allow us to generate a series of results corresponding to different 'build-out' sizes in the park. This information may also be used, relatively easily, to sketch out the economic impact of a build-out of a given scope (type of activity) and size (measured by assets) on the four variables of interest—output, earnings, employment, and state tax revenue relatively easily.

"Park 1" Minimal asset investment of $50,000 each in all five industries:
Increase in Sales = $125,000 + $85,000 + $90,000 + $95,000 + $68,200 = **$463,200** (from Tables 7-1 through 7-5).

Increase in **total output** across all industries = $463,200 x 1.992 = **$922,694.**[19]

[19] 1.992 is the average of the five output multipliers in column two of Table 7-7.

Increase in total earnings across all industries = {(3/5 x $0.67) + (1/5 x $0.80) + (1/5 x $0.55)} per dollar of total sales x $463,200 = $0.672 x $463,200 = **$311,270.**

Increase in total employment across all industries = {(2/5 x 38.84) + (1/5 x 33.02) + (1/5 x 13.96) + (1/5 x 15.23)} per million dollars of total sales x $463,200 = 27.98 x 0.4632 = **13 additional jobs**.

Increase in state tax revenue across all households and industries = {(2/5 x $0.08) + (1/5 x $0.10) + (1/5 x $0.06) + (1/5 x $0.09)} per dollar of total sales x $463,200 = 0.082 x $463,200 = **$37,982.**[20]

"Park 2" Medium equity build-out of $500,000 each in the five industries: (every result from "Park 1" above is multiplied by a factor of ten).

Increase in sales (from Tables 7-1 through 7-5) = **$4,632,000**
Increase in **total output** across all industries = **$9,226,940.**
Increase in total earnings across all industries = **$3,112,700.**
Increase in total employment across all industries = **130 additional jobs**.[21]
Increase in state tax revenue across all households and industries = **$379,820.**

Table 7-8 summarizes this information.[22]

[20] This figure ignores any rents or other user-charges that may be imposed on tenants of the park.

[21] Even at this scale, there is unlikely to be any noticeable impact on wage rates in the County. As of this writing (January 2007), the County's labor force is approximately 83,500 and these jobs with enterprises in the park would typically not call for highly specialized or skilled workers. So, both in scale, 130 relative to 83,500, and in terms of skill levels, the pool is probably large enough such that wage rates would not change appreciably.

[22] Following the methodology presented here, the interested reader can compute the economic changes associated with any combination of asset investment in the various identified uses. Only two possible cases are presented but there are many other possible combinations.

TABLE 7-8: ECONOMIC IMPACT SUMMARY

Park Size	Output	Earnings	Employment	State Tax Rev.
1-"Small"-- $50,000	$922,694	$311,270	13	$37,982
2-"Medium"-- $500,000	$9,226,940	$3,112,700	130	$379,820

7.5 SUMMARY OF ECONOMIC IMPACT

The economic benefits consequent upon the availability of a stable heat source in a fifteen-acre park depend crucially on the scale of operation and the energy-intensiveness of the user. Using a "medium" build-out as an example, employment statewide (though, concentrated on the Big Island) would rise by 130, sales (output) would increase by approximately $9.2 million, and state tax revenue increase by $380,000. Avoided barrels would vary, depending on the energy-intensity of users and the form in which they would have alternately obtained their heat or energy, but a range of 6,475 to 9,713 avoided barrels of crude oil per year might be expected once the facility is operational and occupied.

7.6 PROMOTIONAL PLAN

In this section, we discuss efforts that might be undertaken to promote a geothermal enterprise park, in light of the economic estimates provided here.

Should the County of Hawaii wish to proceed with a geothermal enterprise park outlined here, it is recommended that responsibility for the project be housed within the County of Hawaii's Public Works, Building Division. This provides a locus of responsibility and interest that should maximize the potential of a geothermal enterprise park.

To locate or relocate, businesses must be convinced that placing their operation in the geothermal enterprise park will improve profitability for them in the short term, long term, or both. Promotion in this area would lie primarily with educational efforts to disseminate the information contained in this report.[23] These efforts might include providing education on how geothermal heat has been used elsewhere to improve the profitability of individual firm operations. It will be important to remember that the prospect of lower-cost energy is only one of a panoply of factors that businesses will consider when making a decision to locate in the geothermal enterprise park. A 'short' list includes issues as diverse as the form and tenure of property rights, their neighbors, transportation (for both inputs and outputs), tax considerations, stability of energy supply, safety, security, and zoning.[24]

To promote this end, the County should explore economically efficient ways of overcoming the current lack of a stable heat source. Currently, PGV appears to have better internal uses of their waste heat, thus would face losses by providing heat to the geothermal enterprise park. In order to promote the park, additional motivation, in the form of tax incentives, might be extended to PGV for providing heat.[25] In addition, tax incentives might be offered to firms drilling additional geothermal wells, e.g. for research purposes.

If another party were willing to pay for drilling wells to achieve a research objective, a geothermal enterprise park might benefit from any resulting heat. An example of a potential research objective might involve researching increases in heat output from using horizontal drilling techniques on geothermal wells. Horizontal drilling might also offer the potential to access

[23] For example, current funding sources for direct users of geothermal heat, are provided in Appendix G: "Geothermal Direct Use Funding Sources", by Robert Arrigoni, Energy Coordinator, County of Hawaii Research and Development. This and other relevant information as it is collected and up-dated should be made publicly known and available to potential end-users.

[24] Of course, many of these concerns are common to any location or re-location decision and not particularly geothermal-related.

[25] Consistent with prevailing or newly drafted legislation.

geothermal resources that lie below the ocean surface. Moreover, techniques developed in such a research effort may have implications for drilling exploration elsewhere.

The benefits of geothermal use on the environment in the form of reduced energy dependence should be promoted. This might be done through a series of community meetings outlining these benefits. If a geothermal enterprise park helps achieve an environmental or political objective beyond those economic motivations outlined in this report, these groups may provide political pressure to make the park a reality.

If there is assured, stable, long term access to geothermal heat for direct use, then at that time a knowledgeable individual should be hired or assigned to communicate the benefits of the geothermal enterprise park to the various constituents, including energy-intensive potential businesses, government agencies, land-owners/lease-holders, community groups, and environmental groups.[26]

Given the negative conclusions in Chapter 3 regarding the availability of waste heat from PGV, and the limited economic benefits that can be expected from a Geothermal Enterprise Park as identified here[27], we recommend that at this time efforts continue to find a source of affordable waste heat.[28] These

[26] This recommendation reflects comments made on October 24, 2007, in a public meeting in Keaau, HI, by Dr. John Lund, P.E., President of the International Geothermal Association and Director of the Geo-Heat Center of the Oregon Institute of Technology who said that "these Enterprise Parks need a champion" to direct them and coordinate activities.

[27] Limited in the sense of not being great enough to warrant the $18 million to $24 million capital cost of drilling new source wells for these enterprise projects alone.

[28] The confounding problem (see Chapter 2) is that larger-scale projects, which are most likely to warrant the large capital expenditure, are inconsistent with the preferences of local, community residents. However, in the absence of an already-available heat source (e.g., a 'PGV'), it is simply not feasible for a group of relatively small users to supply the capital necessary to drill their own wells. It is possible that through time and the on-going County-funded relocation of those most closely affected by current large-scale projects, that larger-scale projects may co-exist in the community with minimum frictions. At that

efforts and others consistent with uses of direct heat might be funded (as noted in Chapter 4 above) by revisiting the uses of the County's Asset Fund whose use may be expanded consistent with original intentions through future legislative action.

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time, attracting a large-scale project, that may coincidentally be a source of affordable waste heat, might be a stronger possibility. However, it is important to note that the County-funded relocation program applies only to those who were living in a specific radius of PGV before the plant was built. Apparently, only a few applicable residences remain, and the demand for the program is low.

CHAPTER 8 – CONCLUSIONS

8.1 PURPOSE OF FEASIBILITY STUDY

The purpose of this study was to determine the feasibility of developing direct uses of geothermal heat in the Kapoho / Pohoiki area of Puna on the Island of Hawaii. The study had the following objectives:

1. Identify geothermal direct use enterprises that are likely to be commercially viable, and acceptable to the Puna communities.
2. Identify possible sites that could be used for geothermal direct use businesses.
3. Identify possible geothermal resources in Kapoho outside of PGV's lease that could be utilized for geothermal direct use.
4. Estimate capital and operational costs.
5. Estimate viable unit costs for heat.
6. Identify positive and negative impacts on the community of a geothermal direct use enterprise park.
7. Research the legal basis for accessing the County of Hawaii's Geothermal Asset and Geothermal Royalty funds.
8. Develop a plan to promote the economic benefits of geothermal direct use in the County of Hawaii

8.2 SUMMARY OF FEASIBILITY STUDY

The feasibility study found that geothermal direct use is technically feasible but only marginally economically feasible in the Kapoho / Pohoiki area.

8.2.1 Geothermal Direct Use Enterprises

The Kapoho / Pohoiki area is primarily zoned agricultural and supports mostly agriculture-related industries such as farming. Community opinions solicited through Working Group efforts and through questionnaires suggested that geothermal direct use is supported, provided several conditions are met. Geothermal direct use must support the community, be sustainable, create jobs, and be driven by members of the community.

Four geothermal direct use enterprises emerged as being potentially viable in the Kapoho / Pohoiki area, including greenhouses, pasteurization of potting media, biodiesel production, and lumber kilns. Nine additional geothermal direct use enterprises were determined to have high community appeal and to be potentially beneficial to the community, including fruit drying, seed drying, food processing, papaya disinfection, community commercial kitchen, drying fish, laundromat, university research center, and hot water treatment for coqui eradication. These geothermal direct use enterprises are believed to either consume small quantities of heat or are not anticipated to create significant revenue but were retained for possible small-scale development consideration.

8.2.2 Geothermal Heat Resources

There are basically four means to access geothermal resources in the Kapoho / Pohoiki area including utilizing existing wells, drilling new wells, acquiring "waste heat" from PGV's geothermal power plant, and acquiring "waste heat " from a future geothermal application. Utilizing existing wells and drilling new wells were removed from consideration as a means to access geothermal resources in the Kapoho / Pohoiki area due, respectively, to the limited available heat in shallow aquifers and the significant expense of drilling new deep wells. Acquiring waste heat from PGV is a highly unlikely option because of planned power plant modifications that will reduce the amount of available waste heat and increase the chance of causing scaling problems. It was concluded that the only potentially viable access to geothermal heat in the Kapoho / Pohoiki area would be through a future application of high temperature geothermal heat. This hypothetical future high temperature geothermal heat business would likely be located in the geothermal resource subzones and adjacent to the Pahoa – Kalapana Road (Highway 130) or the Pahoa – Kapoho Road (Highway 132). The targeted source of heat would be spent geothermal fluids that the future business would otherwise inject into the ground.

8.2.3 State and County Regulatory Improvements to Encourage the Direct Use of Geothermal Heat

Most of the State and County of Hawaii's geothermal statutes and rules and regulations focus on exploration and development as they pertain to electricity generation, not to non-electric, or direct, uses of geothermal heat.

There are two particular statutory issues that could have an impact on the feasibility of geothermal direct use: royalties and geothermal funds. Entities that extract energy from geothermal resources are charged royalties by the State of Hawaii. Geothermal direct use could be subject to royalties unless the royalties are waived or legislative changes are made.

The County of Hawaii has established two geothermal funds, the Geothermal Asset Fund and the Geothermal Royalty Fund (i.e., Geothermal Relocation Fund). Both funds have a combined value in excess of $4,000,000 as of December 31, 2006 and it is hoped that some of that money could be used to promote geothermal direct use in the Kapoho / Pohoiki area. County and, possibly, State legislative changes would need to be made before either of the funds could be accessed for geothermal direct use.

8.2.4 Engineering Analysis

It was determined that a hypothetical 15-acre geothermal direct use enterprise park in the Kapoho / Pohoiki area is technically feasible. A hypothetical geothermal direct use enterprise park with mixed tenants is estimated to have a peak heat rate demand of 11 million Btu/hr and an average heat rate demand of 6.6 million Btu/hr. A high-temperature geothermal application, such as PGV's geothermal power plant, could provide

20 million Btu/hr of heat with a very modest temperature drop of 10 degrees F in the spent injected geothermal fluids.

8.2.5 Engineering Cost Analysis

A 15-acre geothermal direct use enterprise park will cost approximately $12.5 million to develop and construct, and $738,000 to operate and maintain in the Kapoho / Pohoiki area. Revenues are estimated to be $1.21 million based on a lease rate of $200/acre-year and a geothermal heat rate priced at $1.32 per therm (100,000 Btu), a 50% discount of the prevailing average fuel rate of diesel and propane. The anticipated payback period for the project is 26 years without financial subsidies, and 7 years with $9.2 million in financial subsidies.

It was concluded that a 15-acre geothermal direct use enterprise park located in the Kapoho / Pohoiki area is at best only marginally economically feasible. "Economically feasible" is defined by this study as the ability to deliver heat energy at a reasonable rate to geothermal direct use customers while maintaining the ability to indefinitely sustain system operations and provide a small return.

8.2.6 Economic Impact

The economic impact of a 15-acre geothermal direct use enterprise park on the Kapoho / Pohoiki community will depend on the amount of investment into each geothermal direct use enterprise. An equal investment of $500,000 each into greenhouse bottom heating, lumber kiln, sterilization of potting media, biodiesel production, and a university research facility would result in $9.2 million in additional sales, 130 new jobs, and $380,000 in additional taxes. Further, these activities would save approximately 8,000 barrels of crude oil per year at this scale of operation.

8.2.7 Promotional Plan

The success of a geothermal direct use enterprise park in the Kapoho / Pohoiki area may depend on implementing a sound promotional plan. One approach is to have the County of Hawaii take the lead as geothermal direct use champion. The County would be responsible for educating and promoting the benefits of geothermal direct use. The County could also explore necessary subsidies through tax breaks or accessing the County's geothermal funds.

8.3 CONCLUSION

In conclusion, 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.

Should it become a reality, geothermal direct use could have a very positive impact on the Kapoho / Pohoiki community by supporting existing agricultural industries, promoting diversified agriculture, creating jobs, and reducing dependence on fossil fuels.

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APPENDIX A
SAMPLE GEOTHERMAL DIRECT USE QUESTIONNAIRE

NON-ELECTRIC (DIRECT) USES OF GEOTHERMAL HEAT
FEASIBILITY STUDY QUESTIONNAIRE

The County is in the process of studying the feasibility of direct (non-electric) uses of geothermal heat in the Kapoho/Pohoiki area of Puna. The goal of this study is to take the first steps to develop a geothermal enterprise park that will benefit the community. The feasibility study is scheduled to be completed by February 2007.

The purpose of this questionnaire is to help us identify geothermal direct use applications acceptable to the communities in the area. We would appreciate you taking some time to fill out this form and we welcome any questions or feedback.

Fact sheets with frequently asked questions are attached for your information.

Geothermal Direct Use Application	Opinion About Application			Interested in Starting a Business Utilizing Geothermal Heat?	Comments?
	Support / Approve	Do Not Support / Disapprove	Neutral		
Aquaculture (Fish Farms)					
Fruit/Vegetable Drying: Bamboo, Bananas, Mangos, Noni, Papayas, Pineapples, etc.					
Greenhouses: Bottom Soil Heating					
Greenhouses					
Soil Treatment: Sterilization of Potting Media					
Seed Drying					
Food Processing: Tea, Vegetable					
Disinfect Papayas					
Community Commercial Kitchen					
Drying Concrete Blocks					
Drying Fish					
Ethanol Distillation (Production)					
Biodiesel Production					
Ice Plant, Cold Storage, and/or Refrigeration					
Laundromat					
Lumber Drying (Kilns)					
Rumbar Production (Planks Made From Used Tires)					
Soap Making					
Bathing Facilities (Public or Private)					
Spas / Onsen					
Swimming Pool					

List any additional geothermal direct use applications you are interested in below:
....
....
....

After reading the attached information on geothermal direct use, how do you feel about using geothermal heat for non-electric purposes? Circle how you feel:

Very Positive   Somewhat Positive   Neutral   Somewhat Negative   Very Negative

Please explain why:...
....
....

It should be noted that we are in the preliminary stages of the study and the recommended list of direct use applications will be edited based on available hot water temperatures, community responses, and feasibility.

We would also like to request some personal information to have a clearer idea of community response to these ideas. Personal information will not be publicly released and you will not be contacted without your permission.

Name:...
Address: ....
....
....
Phone Number: ....
E-mail Address:...
May We Contact You: No / Yes

Please return your questionnaire to either of the following individuals:

Mr. Stephen McPeek
County of Hawaii Resource Center
25 Aupuni Street
Hilo, Hawaii 96720
(808) 961-8085
(808) 935-1205 facsimile
smcpeek@co.hawaii.hi.us

Mr. Tyson Toyama
Okahara & Associates, Inc.
677 Ala Moana Boulevard, Suite 703
Honolulu, Hawaii 96813
(808) 524-1224 x20
(808) 521-3151 facsimile
ttoyama@okahara.com

You may contact Ms. Andrea Gill with the State of Hawaii, Department of Business, Economic Development and Tourism, Strategic Industries Division, Hilo Office for additional information regarding geothermal direct use applications at (808) 933-0312 or andreagill@verizon.net.

Information regarding geothermal direct use applications is also available on-line at the following web sites:

US Department of Energy - http://www.eere.energy.gov/geothermal
DBEDT - http://www.hawaii.gov/dbedt/info/energy/renewable/geothermal
Oregon Institute of Technology - http://geoheat.oit.edu

Harry Kim
Mayor

Jane H. Testa
Director

County of Hawaii

DEPARTMENT OF RESEARCH AND DEVELOPMENT
25 Aupuni Street, Room 219 • Hilo, Hawaii 96720-4252
(808) 961-8366 • Fax (808) 935-1205
E-mail: chresdev@interpac.net

About the Direct Heat Utilization of Geothermal Energy Study

The County of Hawaii, with support from the State and funds from the U.S. Department of Energy, is beginning a study of ways that direct heat from geothermal energy could benefit businesses and the community in lower Puna. Here are some questions and answers about the study.

Q1: What is "direct utilization of geothermal energy"?
"Direct utilization" (or "direct use") means using geothermal heat for non-electric purposes. Worldwide, common direct uses of geothermal energy include aquaculture, drying agricultural products, heating buildings, heating greenhouses, and spas.

Q2: What will the study include?

1) Sharing information on direct uses of geothermal heat with residents of lower Puna (Pahoa, Kapoho, Pohoiki, Leilani Estates, etc.) and discussing their thoughts about direct use opportunities;
2) Conducting a feasibility study to identify costs and benefits of potential direct use business opportunities and to determine if it's a good idea to locate several of the enterprises together in an "incubator" park so that small businesses can test and implement ideas inexpensively; and
3) Learning if support for geothermal direct use is something for which the community thinks the County's existing Geothermal Royalty Fund and Geothermal Asset Fund should be used.

Q3: What kinds of businesses will be studied?
The study will identify a variety of businesses that could make use of geothermal heat. Among the suggestions thus far are: greenhouse bottom heating, lumber drying, pasteurizing growing media for greenhouses, providing cold storage for fishing and other enterprises, aquaculture, spas, and drying fruits, vegetables, or fish. Other ideas that support current agricultural activities in Puna will be sought from residents and businesses in the area.

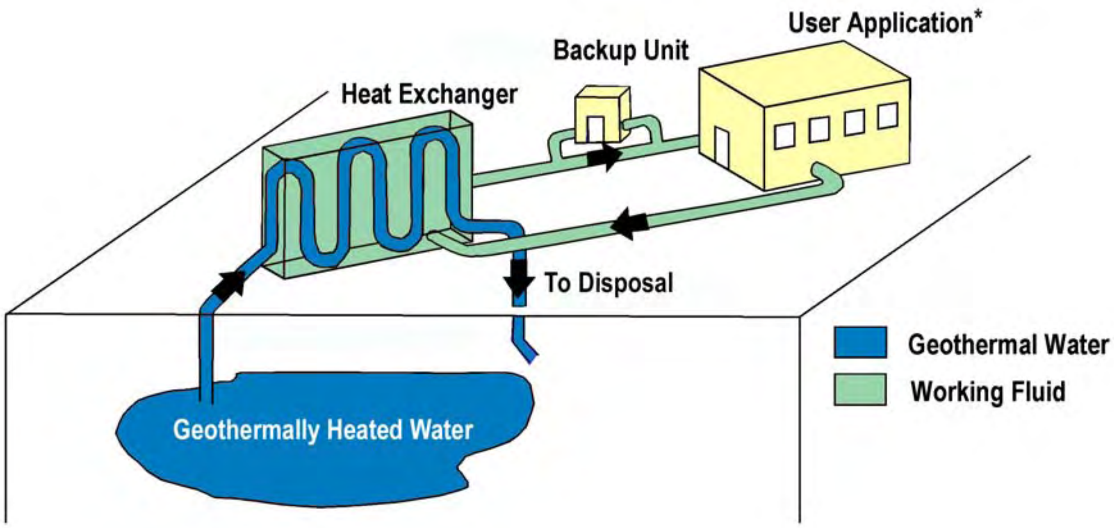
Q4: What hot water resources will be studied?
There are two main resources that could support direct use businesses. One is the waste heat from Puna Geothermal Venture's power plant. The other resource is the hot groundwater that underlies the lower East Rift Zone of Kilauea. This groundwater is naturally heated—between body temperature and boiling—at relatively shallow depths, less than 1,000 feet. It could be pumped to the surface using normal water wells.

Q5: How will information be shared?
The County of Hawaii established a working group to facilitate communication with the community. There will also be public information sessions.

Q6: Will there be any construction, drilling, etc. as part of this project?
No. The project is a feasibility study and does not include any implementation.

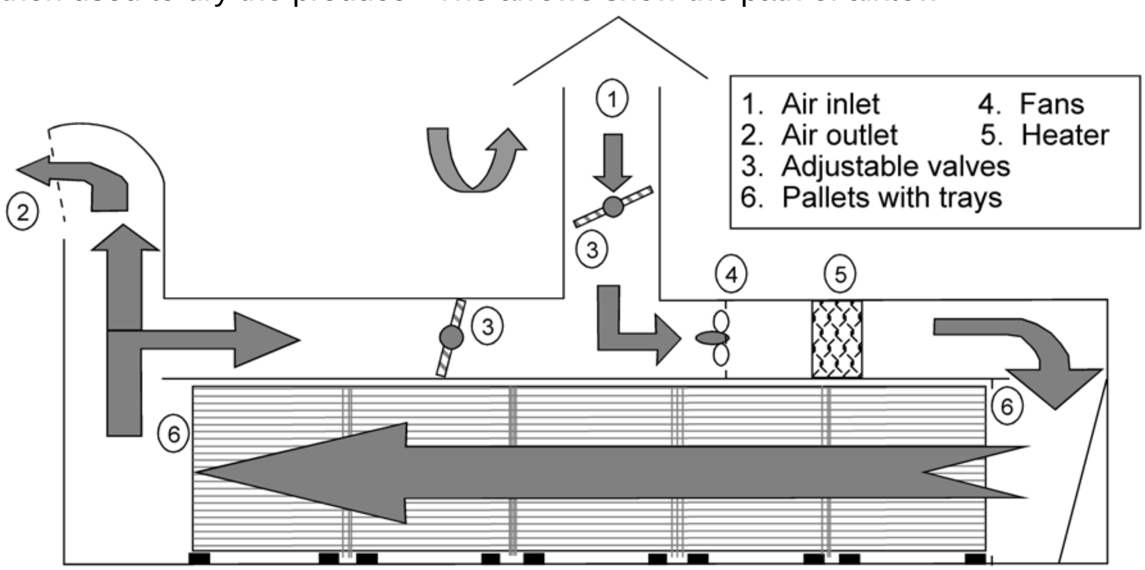
Q7: How long will the study run?
The feasibility study should be completed in early 2007. Discussion and communication with the public will continue throughout the study period.

An Example of Direct Utilization of Geothermal Heat

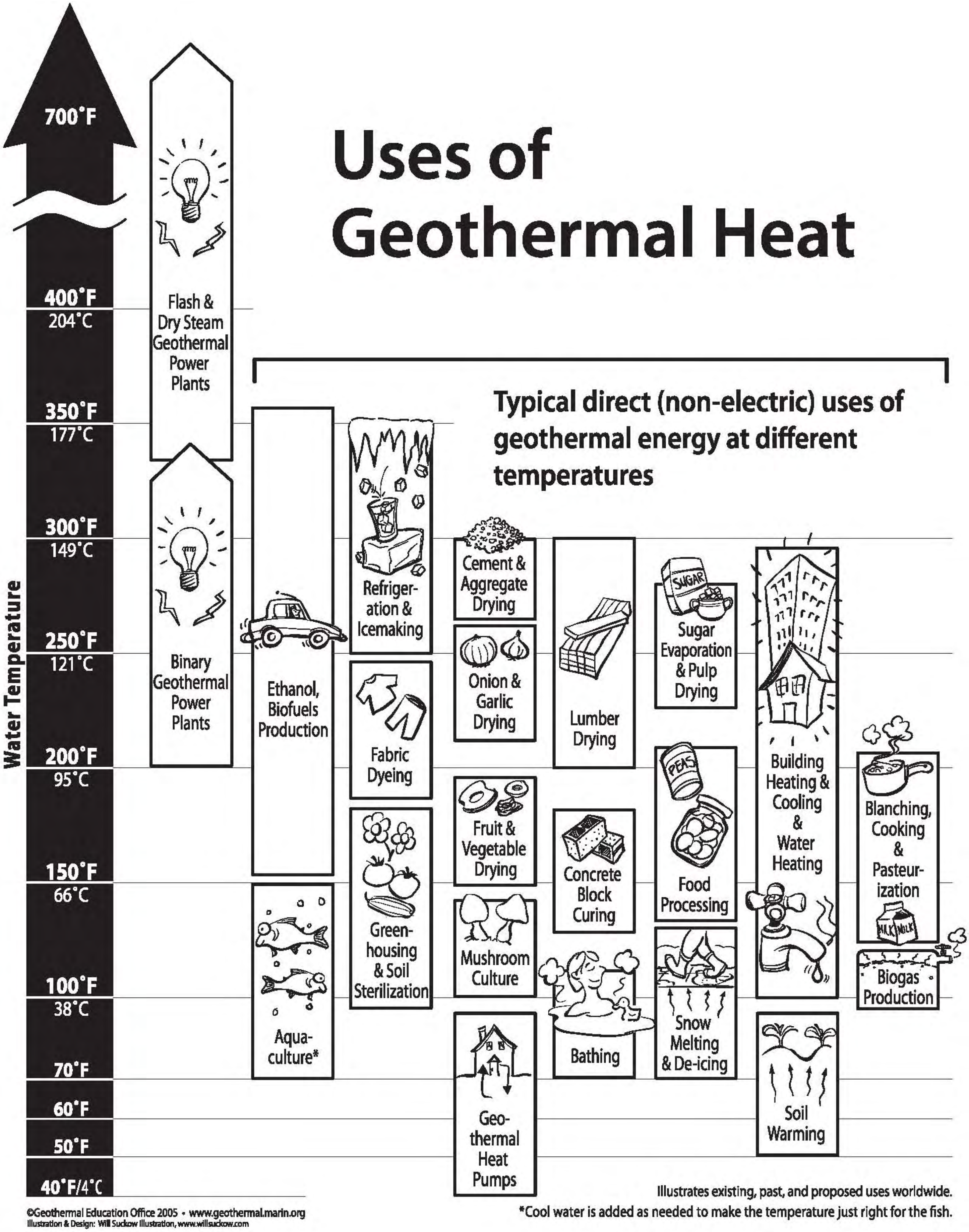


For many direct uses of geothermal heat, hot water is pumped from fairly shallow sources. The heat may be transferred to a “working fluid,” which could be potable water or even air, using a heat exchanger. (In other cases, such as aquaculture or spas, the geothermal water might be used directly, without a heat exchanger.)

*The “user application” could be a dehydration unit for fruit, vegetables or fish, such as the one illustrated below. Heat would be delivered at point #5, the “heater,” which is a heat exchanger. In this illustration, hot geothermal fluid or heated potable water would enter the heat exchanger, and the fan would blow air across it, heating the air, which is then used to dry the produce. The arrows show the path of airflow.



Graphic concepts courtesy of
the U.S. Department of Energy and the Oregon Institute of Technology’s Geo-Heat Center.
Prepared by State of Hawaii Department of Business, Economic Development, and Tourism
in cooperation with the County of Hawaii Department of Research and Development,
January 2005



Uses of Geothermal Heat
Typical direct (non-electric) uses of geothermal energy at different temperatures
Water Temperature
700°F
400°F
204°C
350°F
177°C
300°F
149°C
250°F
121°C
200°F
95°C
150°F
66°C
100°F
38°C
70°F
60°F
50°F
40°F/4°C
Flash & Dry Steam Geothermal Power Plants
Binary Geothermal Power Plants
Ethanol, Biofuels Production
Aqua-culture*
Refriger-ation & Icemaking
Fabric Dyeing
Green-housing & Soil Sterilization
Cement & Aggregate Drying
Onion & Garlic Drying
Fruit & Vegetable Drying
Mushroom Culture
Geo-thermal Heat Pumps
Lumber Drying
Concrete Block Curing
Bathing
SUGAR
Sugar Evaporation & Pulp Drying
PEAS
Food Processing
Snow Melting & De-icing
Building Heating & Cooling & Water Heating
Soil Warming
Blanching, Cooking & Pasteur-ization
MILK
Biogas Production
Illustrates existing, past, and proposed uses worldwide.
*Cool water is added as needed to make the temperature just right for the fish.
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Illustration & Design: Will Suckow Illustration, www.willsuckow.com

APPENDIX B
DIRECT USE RESPONSE LETTERS

May 15, 2006

Edward M. Winkler
PO Box 554
Kurtistown, Hawaii 96760

Tyson Toyama
Okahara & Associates, Inc.
677 Ala Moana Boulevard, Suite 703
Honolulu, Hawaii 96813

Aloha Mr. Toyama:

I am responding to your email of 5/11/06 in regards to use of geothermal heat. I work for Winkler Woods LLC, KW Koa Company LLC and do consulting work in the forest products industry. The companies that I work for have a need to build their own lumber drying facilities as they have a bigger demand for drying than what is available in the State of Hawaii. Currently my employers contract out kiln drying with two operations on the Island of Hawaii. Additionally they send out 70% of their production in sales of green hardwoods to companies in the State of Hawaii where the clients either operate their own electric dehumidification lumber kilns or contract their kiln drying. Affordable kiln drying of lumber produced in the State of Hawaii has always been a problem.

There are several other companies on Hawaii that would have an interest in having their lumber kiln dried by a well engineered facility using up to date technology in the lumber drying industry. A facility that uses geothermal heat for lumber drying would not only benefit my employers but would benefit other Hawaii sawmilling companies. I must assume that a facility could be built that would cost to dry less to dry wood than Hawaii's current electric kilns. Winkler Woods LLC would be interested in participating in the process to develop and market the use of a geothermal heat source lumber drying kiln.

Please find enclosed two pages of the Feasibility Study Questionnaire.

Sincerely,

Edward M. Winkler
Phone: 808-966-9003
Fax: 808-966-9704
Email: ed@winklerwoods.com

Tyson Toyama

From: John Lockwood [jplockwood@volcanologist.com]
Sent: Monday, April 17, 2006 1:34 PM
To: ttoyama@okahara.com
Cc: smcpeek@co.hawaii.hi.us; ron Terry; jimk@usgs.gov
Subject: Geothermal direct-use applications

Dear Tyson and Steve:

Ron Terry forwarded me your "Feasibility Study Questionnaire" regarding direct use possibilities for geothermal heat. I am sending you this reply in lieu of filling out your Questionnaire.

I am an enthusiastic supporter of geothermal energy use and development in Hawaii - especially for non-energy production purposes. I obviously support electric power production too, but because of my background in volcanology, know that geothermal power production from Kilauea's East Rift Zone is subject to Pele's discretion, and feel that over-dependence on geothermal energy for Hawaii (unless back-up capacity is available) is very dangerous. An eruption or below-surface magmatic dike injection into the lower ERZ could suddenly shut down all geothermal production for a very long time......

The development of non-energy uses of geothermal resources is an excellent idea - because the sorts of low-scale usages envisioned could suffer shutdown, without the ruinous impact of loss of non-backed up electrical generating capacity.

I am a Puna resident, live too far from present geothermal resources to utilize any of these proposed low-temperature applications, but believe their development closer to the lower ERZ would be extremely valuable for economic diversification of Hawaii. Of all the proposed uses, I feel that the development of spas & onsen is by far the most important. Quality onsen could be developed at relatively little direct cost, yet would have immense economic benefits by providing incentives for our tourism industry - as well as for local folks.

Good luck with your support of these diversified uses for geothermal energy - they would serve to make Big Islanders much more supportive for geothermal development if such direct benefits were available to small scale entrepreneurs and citizens.

I hope that these comments are of use.

Aloha No,

Jack

John P. Lockwood

GEOHAZARDS CONSULTANTS INTERNATIONAL, INC.
Appraisal of Hazards --- Reduction of Risk
P.O. Box 479, Volcano, Hawaii 96785 USA [Physical Address: 19-4260 Alanui Iiwi, Volcano, Hawaii 96785]
Tel: 1-808-967-8579, FAX: 1-808-967-8525
E-mail: geohaz@hawaii.rr.com; gci@volcanologist.com, Web Pages:

http://www.volcanologist.com/pages/gci.html

2/12/2007

KAPOHO MANAGEMENT COMPANY, INC., General Partner for
KAPOHO LAND PARTNERSHIP (a Hawaii Limited Partnership)
808-935-5810
P. O. Box 3896
Honolulu, Hawaii 96812-3896
P. O. Box 374
Hilo, Hawaii, 96720

June 14, 2006

Mr. Donald Okahara, P.E., President
Mr. Tyson Toyama, P.E., Senior Associate
Okahara and Associates, Inc.
Suite 703, 677 Ala Moana Boulevard
Honolulu, Hawaii 96813

Dear Donald and Tyson:

Kapoho Management Company, Inc. (KMC) general partner for Kapoho Land Partnership (KLP) a Hawaii General Partnership, is pleased to provide input on the study your firm is conducting concerning secondary uses related to geothermal development.

KLP supports the development of secondary uses of geothermal resources on lands controlled by Kapoho Land Partnership (KLP). Currently, 815-acres of lands controlled by KLP are being developed by Puna Geothermal Venture (PGV), and it is our understanding that these lands have the hottest and highest-pressure geothermal resource in the world.

One perspective for studying the viability of secondary uses at Kapoho is considering the secondary geothermal uses that have successfully been developed in other locales throughout the world with developed geothermal resources. One example worth examining is Iceland's use of geothermal generated electricity to produce hydrogen as an exportable energy resource.

In 1981, KLDC transferred to KLP the mining and subsurface rights, including the geothermal rights and all mineral rights, and entered into a long-term surface lease for the 815-acres that PGV is developing. PGV has a resource lease with KLP for the aforementioned 815-acres, and also sub leases surface areas from KLP. In 1983, KLDC also transferred to KLP similar rights for about 1,150 acres comprising the Kula lands, and entered into a long-term surface lease with KLP.

In early-1981, the State of Hawaii issued Geothermal Resource Mining Lease No. R-2 (GRMLR2), for the 815-acres. In issuing GRMLR2, the State acknowledged that the State's claim to ownership of the geothermal resource was unsettled, and today the ownership issue remains unsettled.

KLP retains rights to the excess water and heat that PGV does not utilize to produce electrical energy.

If you have any questions regarding this letter, please do not hesitate to contact me.

Aloha nui loa,

Lono Lyman, ~~President Kapoho~~ Management Company, Inc.
and Manager, Kapoho Land Partnership

KAPOHO LAND and DEVELOPMENT COMPANY, LIMITED

808-935-5810
P. O. Box 3896
Honolulu, Hawaii 96812-3896
P. O. Box 374
Hilo, Hawaii, 96720

June 14, 2006

Mr. Donald Okahara, P.E., President
Mr. Tyson Toyama, P.E., Senior Associate
Okahara and Associates, Inc.
Suite 703, 677 Ala Moana Boulevard
Honolulu, Hawaii 96813

Dear Donald and Tyson:

Kapoho Land and Development Company, Limited (KLDC) is pleased to provide input on the study your firm is conducting concerning secondary uses related to geothermal development. KLDC supports the development of secondary uses of geothermal resources on lands controlled by Kapoho Land Partnership (KLP). Currently, 815-acres of lands controlled by KLP are being developed by Puna Geothermal Venture (PGV), and it is our understanding that these lands have the hottest and highest-pressure geothermal resource in the world.

In 1981, KLDC transferred to KLP the mining and subsurface rights, including the geothermal rights and all mineral rights, and entered into a long-term surface lease for the 815-acres that PGV is developing. In 1983, KLDC also transferred to KLP similar rights for about 1,150 acres comprising KLDC's Kula lands, and entered into a long-term surface lease with KLP. KLP will comment separately on your study.

KLDC also owned the fee interest in the lands that became the HGP-A site, and in the 1970s transferred the site to the State of Hawaii under the treat of condemnation. Subject to verification, it is recalled that KLDC reserved certain rights to revenues derived from any and all commercial uses located on the site.

If you have any questions regarding this letter, please do not hesitate to contact me.

Aloha nui loa,

A. Lono Lyman, Manger
Kapoho Land and Development Company, Limited

APPENDIX C
LIST OF STATE AND COUNTY STATUTES AND RULES AND REGULATIONS

TABLE C-1: LIST OF STATE AND COUNTY STATUTES AND RULES AND REGULATIONS

HAWAII DEPARTMENT OF LAND AND NATURAL RESOURCES	
Conservation District Use Permit	Hawaii Revised Statutes (HRS) Chapter 183; Hawaii Administrative Rules (HAR) Title 13, Chapter 2
Geothermal Exploration Permit	HRS Chapters 174C and 182; HAR, Title 13, Chapter 183
Geothermal Well Drilling Permit	HRS Chapters 174C and 182; HAR, Title 13, Chapter 183
Geothermal Well Modification Permit	HRS Chapters 174C and 182; HAR, Title 13, Chapter 183
Geothermal Well Abandonment Permit	HRS Chapters 174C and 182; HAR, Title 13, Chapter 183
Geothermal Resource Mining Lease	HRS Chapter 182; HAR, Title 13, Chapter 183
Geothermal Plan of Operations	HRS Chapter 182; HAR, Title 13, Chapter 183
Geothermal Resource Subzones	HRS Chapter 205; HAR, Title 13, Chapter 184
Water Rights	HRS Chapter 174C; HAR, Title 13, Chapters 167-171
HAWAII DEPARTMENT OF HEALTH	
Underground Injection Control Permit: Approval to construct and Permit to Operate	40 CFR Part 144 through 147; HRS Chapter 340E; HAR, Title 11, Chapter 23
Authority to Construct and Permit to Operate	Clean Air Act (42 USC); HRS Chapter 342B; HAR, Title 11, Chapters 59 and 60
NPDES Permit	HAR, Title 11, Chapter 55
Wastewater Discharge	HAR, Title 11, Chapter 62
COUNTY OF HAWAII	
Geothermal Resource Permit	HRS Chapter 205; Hawaii County Planning Commission, Rule 12
Grading, Grubbing and Stockpiling Permit	Hawaii County Code, 1983, Chapter 10, Articles 2 and 3
Building Permit	Hawaii County Code, 1983, Chapter 5 and Chapter 14, Article 9
Electrical Permit	Hawaii County Code, 1983, Chapter 9, Article 5, Division 1
Plumbing Permit	Hawaii County Code, 1983, Chapter 17, Article 2

APPENDIX D
SAMPLE LEGISLATION
APP. D1: SAMPLE STATE LEGISLATION
APP. D2: SAMPLE COUNTY LEGISLATION

APPENDIX D1: SAMPLE STATE LEGISLATION

SECTION 1: Purpose. When statutory provisions relating to geothermal energy were first enacted in the 1980s, the focus of legislation was on electricity production. Use of geothermal resources was considered one potential way to decrease the use of and dependence on fossil fuels. The provisions relating to geothermal energy in this chapter were enacted to establish a statutory structure for the payment of royalties to the State of Hawaii by lessees utilizing geothermal resources primarily for electricity generation.

The Legislative history relating to the royalty provisions evidences a strong intent by the Legislature to encourage the development of geothermal energy. The 1985 legislation which established the geothermal royalty provision included a waiver provision for "encouraging exploration and development as well as the continued production of geothermal resources which would not otherwise have been undertaken because of prohibitive financial costs." Senate Standing Committee Report No. 301 by the Committee on Energy on Senate Bill No. 153. In 1990, the definition of "geothermal resources" was amended to exclude resources of "150 degrees Fahrenheit or less, and not used for electrical power generation." The purpose of the amendment was to promote nonelectric uses of geothermal energy such as the bottling and sale of mineral water and spa and resort development. Committee on Energy and Natural Resources, on Senate Bill No. 3285.

The purpose of this bill is to further encourage direct uses for geothermal energy for purposes other than electrical generation. There have been various concepts studied over the years to utilize geothermal resources for community oriented economic development such as fine cloth dying, glassblowing and wood drying. One potential impediment to such use is the uncertainty as to whether these direct uses of geothermal resources would be subject to the payment of royalties under this section.

This bill proposes two concepts to promote direct use. First, certain direct uses would be exempted from royalty payments. Second, this bill would clarify the intent and purpose of the county allocation of geothermal royalties.

This bill amends Section 182-18, Hawaii Revised Statutes, by exempting certain uses of geothermal resources from the payment of royalties in order to promote the development of other environmentally responsible, community oriented direct uses of geothermal resources to support artistic, agricultural and research activities. To provide the State flexibility in the event that direct uses become very economically productive, a renewal provision is inserted in this bill as well as a limit on the amount of economic benefit which a direct user could derive from the exemption.

Further, this bill clarifies the intent and purpose of the county allocation of geothermal royalties. Section 187-2 (c) contains a provision enacted in 1991 which requires that 30% of geothermal royalties paid to the State be allocated to the county in which the mining lease is situated. Although the 1991 amendment imposes no restrictions on the use of the revenue by the receiving county, the legislative history only mentions the mitigation of negative impacts as the purpose for the county allocation:

> …a significant portion of geothermal royalties should be made available to the local government where the resource is located. Sharing this source of revenue mitigates the negative impacts of geothermal development. Standing Committee Report No. 382 by the Committee on Planning, Land and Water Use Management on Senate Bill No. 1523

This bill clarifies that the mitigating actions could include efforts to promote energy self-sufficiency, conservation, environmental protection, research and development, relocation of affected owner-occupants and any other mitigating actions as determined by the county receiving the funds.

SECTION TWO: Section 182-7 (c), Hawaii Revised Statutes, is amended to read as follows:

(c) The payments to the State as fixed by the board shall be specified; provided that:

(1) In the case of bauxite, bauxitic clay, gibbsite, diaspore, boehmite, and all ores of aluminum, the amount of royalties for each long dry ton of ore as beneficiated shall not be less than twenty-five cents or the equivalent of the price of one pound of virgin pig aluminum, whichever is higher, nor shall it exceed the equivalent of the price of three pounds of virgin pig aluminum;

(2) The rate of royalty for ore processed into aluminous oxide in the State shall be set at eighty per cent of the rate of royalty for ore not processed to aluminous oxide in the State; and

(3) The royalty shall be fixed at a rate which will tend to encourage the establishment and continuation of the mining industry in the State.

The prices of virgin pig aluminum for the purpose of determining the royalties under this section shall be the basic price on the mainland United States market for virgin pig, not refined, f.o.b. factory. The royalties shall be in lieu of any severance or other similar tax on the extracting, producing, winning, beneficiating, handling, storing, treating, or transporting of the mineral or any product into which it may be processed in the State, and shall not be subject to reopening or renegotiating for and during the first twenty years of the lease term.

In the event the lessee desires to mine other minerals, the lessee, before mining the minerals, shall so notify the board in writing, and the board and the lessee shall negotiate and fix the royalties for the minerals.

Any other law to the contrary notwithstanding, thirty per cent of all royalties received by the State from geothermal resources shall be paid to the county in which mining operations covered under a state geothermal resource mining lease are situated. <u>These funds may be used to mitigate the impacts of geothermal energy, promote energy self-sufficiency, resource conservation, environmental protection, research and development, relocation of affected owner-occupants and any other mitigating actions as determined by the county receiving the funds.</u>

SECTION THREE: Section 182-18, Hawaii Revised Statutes, is amended to read as follows:

"§182-18 Geothermal royalties.

(a) The board shall fix the payment of royalties to the State for the utilization of geothermal resources at a rate which will encourage the initial and continued production of such resources. With respect to all geothermal mining leases previously issued or to be issued, where the board determines that it is necessary to encourage the initial or continued production <u>or use</u> of geothermal resources, the board shall have the authority to waive royalty payments to the State for any fixed period of time up to but not exceeding eight years.

(b) The board shall adopt, amend, or repeal rules pursuant to chapter 91 to establish the basis upon which the amount and duration of royalty payments to the State will be fixed or waived. The board's assessment of each application shall include, but not be limited to, the examination of such factors as the progress of geothermal development taking place in the State at the time of the application, the technical and financial capabilities of the applicant to undertake the project, and the need for providing a financial incentive in order for the applicant to proceed. The granting of any favorable terms to an applicant for the payment of royalties under this section may be revoked by the board if the applicant fails to satisfy any of the terms and conditions established by the board, or if the applicant wholly ceases operations and for reasons other than events which are outside the control of the parties and which could not be avoided by the exercise of due care by the parties.

(c) The board shall submit a written report of all geothermal royalty dispositions to the legislature in accordance with section 171-29.

(d) Notwithstanding any other provision to the contrary, the following shall be exempt from the payment of royalties:

(1) direct uses of geothermal resources for activities conducted at a facility owned and controlled by a county to promote energy self-sufficiency, research, development and other legitimate uses; and
(2) direct uses, other than electricity generation, by parties other than the lessee or entities controlled by the lessee, for which the lessee has not charged direct user for the direct use of the geothermal resource; and
(3) any other direct use determined by the board pursuant to criteria which shall be promulgated by the board pursuant to chapter 91;

provided that, this provision shall expire on July 1, ____________, unless renewed; and provided further that this exemption shall not be available for a direct user for any tax year following a tax year in which the net taxable income for the direct user resulting from the direct use exceeded ______________________."

APPENDIX D2: SAMPLE COUNTY LEGISLATION

SECTION ONE: Purpose. When State statutory provisions relating to geothermal energy were first enacted in the 1980s, the focus of legislation was on electricity production. Use of geothermal resources was considered one potential way to decrease the use of and dependence on fossil fuels. The provisions relating to geothermal energy in Chapter 182, Hawaii Revised Statutes, were enacted to establish a statutory structure for the payment of royalties to the State of Hawaii by lessees utilizing geothermal resources. Those provisions require that thirty per cent of all geothermal royalties be paid to the County in which the royalties are generated.

The County of Hawaii established two funds for proceeds from the royalties and for separate fees assessed Puna Geothermal Venture. A Geothermal Asset Fund (§ 2-176, Hawaii County Code) was created in 1995 for the utilization of fees paid by Puna Geothermal Venture(Ordinance No. 95-74) and a Relocation Program (§ 2-177, Hawaii County Code) was established in 1996 to utilize the County's share of the royalties (Ordinance No. 96-2.)

As of December 31, 2006, there were $1,863,620 in the Asset Fund. The last claim was paid in 2005.

As of December 31, 2006, there were $2,205,097 in the relocation fund. Through the program, the County purchased four dwellings and resold them. The last purchase was made in the year 2003.

The purpose of this bill is to expand the potential uses for the funds, including the promotion of environmentally responsible, community oriented direct uses of geothermal energy.

SECTION TWO: Section 2-176, Hawaii County Code, is amended to read as follows:

“Section 2-176. Creation of fund. Pursuant to section 10-12, Hawai'i County Charter, a special fund to be known as the geothermal asset fund is created.

(a) The Geothermal asset fund shall be funded by payments made by Puna Geothermal Venture, a Hawai'i Partnership, its successors or assigns and the State of Hawai'i for the purpose of compensating persons impacted by geothermal energy development activities pursuant to the provisions incorporated in Geothermal Resource Permit No. 2.

(b) Payments from the asset fund shall be administered and expended in accordance with rules, regulations and procedures developed for that purpose and adopted by the Hawai'i County Planning Commission in accordance with chapter 91, Hawai'i Revised Statutes.

(c) Expenses incurred by the planning commission such as administrative costs related to geothermal resource permits, geothermal development compliance activity and processing of claims against the asset fund shall not be charged to the asset fund.

(d) All interest and earnings accrued from the money and assets deposited in the asset fund shall be expended for the purposes for which this fund has been created.

(e) No claim made pursuant to this section will be deemed a claim against the county, nor will the payment of any claim be construed as an admission of fault by the county or its officers, employees or agents.

(f) The denial of any claim made under this Geothermal Asset Fund, in whole or in part, shall not prevent the claimant from pursuing any other remedy at law against the geothermal permittee and State of Hawai'i.

(g) The funds may be used for direct uses of geothermal resources for activities to promote energy self-sufficiency, research, development and other legitimate uses; provided these uses are consistent with the conditions imposed by Geothermal Permit No. 2."

SECTION THREE: Section 2-181, Hawaii County Code, is amended to read as follows:

"Section 2-181. Expenditures from fund. The proceeds from the fund shall be used for the necessary expenses in administering and carrying out the purposes of the geothermal relocation program. Expenditures relating to the geothermal relocation program include but are not limited to:

(a) The costs of any necessary appraisals required under this program;

(b) The payment of necessary fees and expenses;

(c) The costs for the purchase of an affected dwelling and property in accordance with this chapter, if necessary; [~~and~~]

(d) The costs necessary to dispose of or rent affected dwelling and property [.]

(e) In a fiscal year following a fiscal year in which no relocations are made, an amount equal to 90% of the royalties generated in the fiscal in which no relocations were made, may be used to promote direct uses of geothermal resources, except for electricity generation."

APPENDIX E
COST ESTIMATE WORKSHEETS

TABLE E-1: NON-GEOTHERMAL CAPITAL COSTS
SUBDIVISION COST ESTIMATE
(2007-COSTS)

ITEM	QUANTITY	UNITS	UNIT COST ($)	TOTAL ($)
CLEAR AND GRUB	15	AC	10,000	150,000
EARTHWORK	1	LS	2,417,000	2,417,000
AC PAVEMENT	1	LS	403,000	403,000
TRAFFIC CONTROL	1	LS	5,000	5,000
WATER LINE	1	LS	106,000	106,000
DRYWELLS	6	EA	20,000	120,000
ELECTRICITY	1	LS	100,000	100,000
CONTINGENCY (25%)	1	LS	825,250	825,250
CONSTRUCTION MANAGEMENT (10%)	1	LS	412,625	412,625
MOBILIZE/DEMOBILIZE (5%)	1	LS	226,944	226,944
OVERHEAD & PROFIT (15%)	1	LS	714,873	714,873
INSURANCE (15%)	1	LS	822,104	822,104
TAXES (4.17%)	1	LS	262,827	262,827
BOND (1.5%)	1	LS	98,484	98,484
DESIGN FEES (6%)	1	LS	399,846	399,846
SUBTOTAL				7,063,953
REDUCTION OF 1/13 COVERED BY GEOTHERMAL COSTS				-543,381
TOTAL				**6,520,572**

Assumptions:
1. Significant grading will not be required.
2. Roadways, electricity and water are located adjacent to the proposed subdivision.
3. Roadway improvements such as turning lanes will not be required by the County.

TABLE E-2: GEOTHERMAL CAPITAL COSTS
(2007-COSTS)

COST ESTIMATE ANALYSIS

Geothermal Direct Use Cost Estimate	**Job No.**	EFFECTIVE PRICING DATE **January 2007**	DATE PREPARED **Jan 27, 2007**
PROJECT: **Geothermal Direct Use Feasibility Study**	**Feasibility Study Cost Estimate**	Drawing No.	**PAGE 1 OF 3 SHEETS**
LOCATION: **Kapoho / Pohoiki Area**		ESTIMATOR: **T. Toyama**	CHECKED BY : **T. Toyama**

TASK DESCRIPTION	QUANTITY		LABOR				LAB/MAT		MATERIAL		TOTAL	SHIPPING	
	No. Of Units	Unit Meas.	M H Unit	Total Hrs.	Unit Price	Cost	Unit Price	Cost	Unit Price	Cost		Unit Wt.	Total Wt.
GEOTHERMAL													
1. Heat Exchanger	3	EA	133.00 mh	**399.00**	72.50	**28927.50**			110000.00	**330000.00**	**358,927.50**		
2. Pumps (1,000 gpm)	4	EA	20.00 mh	**80.00**	72.50	**5800.00**			10700.00	**42800.00**	**48,600.00**		
3. VSDs (40 hp)	4	EA	24.00 mh	**96.00**	72.50	**6960.00**			8450.00	**33800.00**	**40,760.00**		
4. Storage Tank (5,000 gal.)	1	EA	10.00 mh	**10.00**	72.50	**725.00**			7000.00	**7000.00**	**7,725.00**		
5. Air Separator	2	EA	16.00 mh	**32.00**	72.50	**2320.00**			4000.00	**8000.00**	**10,320.00**		
6. Chemical Feed (10 gal)	1	EA	18.00 mh	**18.00**	72.50	**1305.00**			710.00	**710.00**	**2,015.00**		
7. 2" Backflow Preventer	1	EA	2.00 mh	**2.00**	72.50	**145.00**			1235.00	**1235.00**	**1,380.00**		
8. 12" Flow Meter	1	EA	14.00 mh	**14.00**	72.50	**1015.00**			4600.00	**4600.00**	**5,615.00**		
9. 8" Flow Meter	2	EA	8.00 mh	**16.00**	72.50	**1160.00**			1350.00	**2700.00**	**3,860.00**		
10. 4" Flow Meter	11	EA	1.50 mh	**16.50**	72.50	**1196.25**			725.00	**7975.00**	**9,171.25**		
11. 12" SST Shutoff Valves	2	EA	15.00 mh	**30.00**	72.50	**2175.00**			14715.00	**29430.00**	**31,605.00**		
12. 8" Shutoff Valves	20	EA	10.00 mh	**200.00**	72.50	**14500.00**			5320.00	**106400.00**	**120,900.00**		
13. 4" Shutoff Valves	22	EA	6.00 mh	**132.00**	72.50	**9570.00**			2015.00	**44330.00**	**53,900.00**		
14. 6" Check Valves	4	EA	8.00 mh	**32.00**	72.50	**2320.00**			785.00	**3140.00**	**5,460.00**		
15. 4" Pressure Reducing Valve	1	EA	2.00 mh	**2.00**	72.50	**145.00**			3215.00	**3215.00**	**3,360.00**		
16. 8" FRP Pipe	4300	LF	.49 mh	**2107.00**	72.50	**152757.50**			23.00	**98900.00**	**251,657.50**		
17. 8" Insulation (2" Cell Glass)	4300	LF			72.50				15.27	**65661.00**	**65,661.00**		
18. 8" Jacket	4300	LF			72.50				3.10	**13330.00**	**13,330.00**		
19. Tank/Pump Insulation	1000	SF	.32 mh	**320.00**	72.50	**23200.00**			4.13	**4130.00**	**27,330.00**		
20. Trenching/Backfill	2000	CYD			72.50		380.00	**760000.00**			**760,000.00**		
21. Pump/Tank House	1000	SF			72.50		300.00	**300000.00**			**300,000.00**		
22. Control House	500	SF			72.50		300.00	**150000.00**			**150,000.00**		
23. Meter Vaults	15	EA			72.50		12000.00	**180000.00**			**180,000.00**		
TOTAL THIS SHEET			Total Hours:	**3506.50 th**	Labor Cost:	**254221.25**	Equip. Cost:	**1390000.00**	Material Cost:	**807,356.00**	**2,451,577.25**	Total Weight:	

TABLE E-2: GEOTHERMAL CAPITAL COSTS
(2007-COSTS)

COST ESTIMATE ANALYSIS **Geothermal Direct Use Cost Estimate**	**Job No.**	EFFECTIVE PRICING DATE **January 2007**	DATE PREPARED **Jan 27, 2007**
PROJECT: **Geothermal Direct Use Feasibility Study**	**Feasibility Study**	Drawing No.	**PAGE 2 OF 3 SHEETS**
LOCATION: **Kapoho / Pohoiki Area**	**Cost Estimate**	ESTIMATOR: **T. Toyama**	CHECKED BY : **T. Toyama**

TASK DESCRIPTION	QUANTITY		LABOR				LAB/MAT		MATERIAL		TOTAL	SHIPPING	
	No. Of Units	Unit Meas.	M H Unit	Total Hrs.	Unit Price	Cost	Unit Price	Cost	Unit Price	Cost		Unit Wt.	Total Wt.
GEOTHERMAL CONTINUED													
1. Control Points	50	EA			72.50		2000.00	**100000.00**			**100,000.00**		
TOTAL THIS SHEET			Total Hours:		Labor Cost:		Equip. Cost:	**100000.00**	Material Cost:		**100,000.00**	Total Weight:	

TABLE E-2: GEOTHERMAL CAPITAL COSTS
(2007-COSTS)

COST ESTIMATE ANALYSIS

Geothermal Direct Use Cost Estimate

PROJECT: **Geothermal Direct Use Feasibility Study**	Job No.	EFFECTIVE PRICING DATE **January 2007**	DATE PREPARED **Jan 27, 2007**
LOCATION: **Kapoho / Pohoiki Area**	**Feasibility Study Cost Estimate**	Drawing No.	**PAGE 3 OF 3 SHEETS**
		ESTIMATOR: **T. Toyama**	CHECKED BY : **T. Toyama**

TASK DESCRIPTION	QUANTITY		LABOR				EQUIPMENT		MATERIAL		TOTAL	SHIPPING	
	No. Of Units	Unit Meas.	M H Unit	Total Hrs.	Unit Price	Cost	Unit Price	Cost	Unit Price	Cost		Unit Wt.	Total Wt.
GEOTHERMAL SUBTOTAL PAGE 1											**2,451,577.25**		
GEOTHERMAL SUBTOTAL PAGE 2											**100,000.00**		
SUBTOTAL											**2,551,577.25**		
TESTING AND COMMISSIONING @ 5%											**127,578.86**		
CONTINGENCIES @35%											**937,704.64**		
MOB/DEMOB @ 10%											**361,686.08**		
OH AND PROFIT@ 15%											**596,782.02**		
TAX @ 4.17%											**190,791.21**		
BOND @ 1.5%											**71,491.80**		
DESIGN FEES @12.5%											**604,701.48**		
TOTAL GEOTHERMAL											**5,442,313.35**		
SAY											**5,443,000.00**		
SITE DEVELOPMENT COSTS FOR 1-ACRE FROM CIVIL COST ESTI											**543,381.00**		
TOTAL GEOTHERMAL & 1 ACRE OF SITE DEVELOPMENT											**5,985,694.35**		
SAY											**5,986,000.00**		
TOTAL THIS SHEET			Total Hours:		Labor Cost:		Equip. Cost:		Material Cost:			Total Weight:	

Geothermal Hot Water Circulating Pump Electricity Consumption Calculations

Given: 6.6 million Btu/hr average geothermal enterprise park heat consumption (See Chapter 3)
Specific heat of water = 1.0 Btu/(lbm*deg F)
Density of water = 8.33 pounds/gallon

Assumptions:
Primary Loop Delta T = 10 degrees F
Primary Loop Delta P = 12 psi
Secondary Loop Delta T = 40 degrees F
Secondary Loop Delta P = 40 psi
Pump Motor Efficiency = 90%
Pump Efficiency = 80%
Electricity Rate = $0.35 per kWh

Calculate Primary Loop Hot Water Flow Rate

$Q = q/(c_p\text{*Delta T})$

Where:
Q = Hot Water Flow Rate (gpm)
q = Heat Flow Rate (Btu/hr)
c_p = Specific Heat of Water (Btu/(lbm*deg F))
Delta T = Change in Hot Water Temperature (degrees F)

Q = [(6.6x10^6 Btu/hr)*(1 gallon/8.33 pounds)*(1 hr/60 min)]/[(1.0 Btu/(lbm*deg F))*(10 degrees F)]
= 1,320 gpm

Calculate Secondary Loop Hot Water Flow Rate

Q = [(6.6x10^6 Btu/hr)*(1 gallon/8.33 pounds)*(1 hr/60 min)]/[(1.0 Btu/(lbm*deg F))*(40 degrees F)]
= 330 gpm

Calculate Primary Loop Pump Electricity Consumption

$W = (\text{Delta p})(Q)/[(1714)*n_{pump}*n_{motor}]$

Where:
W = Power (hp)
Delta p = Change in Hot Water Pressure (psi)
n = Efficiency

W = (12 psi)*(1,320 gpm)/[(1714)*(0.9)*(0.8)] = 12.8 hp = 9.5 kW

Calculate Secondary Loop Pump Electricity Consumption

W = (40 psi)*(330 gpm)/[(1714)*(0.9)*(0.8)] = 10.7 hp = 8 kW

Calculate Cost of Electricity Consumed Per Year

Cost = (9.5 kW + 8 kW)*(24 hours/day)*(365 days/year)*($0.35/kW-hr) = $53,655 per year

APPENDIX F
ASSET-TO-SALES METHOD AND ECONOMIC IMPACT DATA FROM RISK MANAGEMENT ASSOCIATES

APPENDIX F – METHODOLOGY FOR ESTIMATING FINANCIAL STATEMENTS

F.1 INTRODUCTION

In this appendix, the financial statements of firms in candidate industries are estimated (pro-forma statements). A set of Pro-forma financial statements can be used as an input in estimating the overall impact of a project on the economy, as noted in the text of this document. In addition, pro-forma financial statements provide information on other feasibility issues of a project. Data that can be gleaned from pro-forma financial statements include the amount of sales that can be produced from a given equity investment, the total amount of bank financing that is necessary to undertake a project, and the extent of external resources necessary to achieve a given level of sales.

A comparables methodology was used to estimate pro-forma financial statements. The comparables analysis starts by identifying the industry in which the proposed firm operates. Next, industry average information for each identified industry is acquired. Finally, the industry average financial information is used to estimate pro-forma financial statements for each firm in the park.

F.2 IDENTIFYING APPROPRIATE INDUSTRIES

As noted above, the first step in estimating financial pro-forma financial statements is to select the appropriate comparison industry. The comparison industry must correspond to an industry where average financial data are compiled by national organizations and made publicly available. One commonly cited source of financial information is the Risk Management Association, Annual Statement Studies.

Industries reported in Risk Management Association Annual Statement Studies (RMA) are, to varying degrees, generalized. Obtaining a precise industry match for a particular project is generally not possible. Not knowing the exact nature of the project to be undertaken in advance exacerbates the situation. Moreover, some firms fall between several industry definitions. Thus, to complete the analysis, the first step is to select an appropriate industry based on the restrictions confronted.

At least two options are available for determining the appropriate industry when multiple candidates are present. The first option is to estimate the financial statements for each candidate industry. The end user can then select the statements that most closely correspond to the exact characteristics of the project undertaken. The second option is to average RMA estimates across several candidate industries to produce a single overall measure. In this report, the first option is followed, reporting financial statement estimations for several candidate industries, allowing the end user to make a selection based on the precise nature of the business that will be determined at a future date. Financial statement estimations are provided for several industries, where the firms in question typically are classified. Financial statement estimations are provided for each industry identified in Table F-1. A full description of each industry is contained in Table F-2. Two industry alternatives were selected for greenhouse operations, three for soil sterilization, two for fish/food dehydrating, two for lumber kilns and two for a university research center. A single industry was selected for papaya processing and ethanol/biodiesel.

TABLE F-1: COMPARISON INDUSTRIES

Industry	NAICS	SIC	Sample Size	Description
Greenhouse A	424930	5193	141	Flower Nursery Stock, and Florists' Supplies Merchant Wholesalers

TABLE F-1: COMPARISON INDUSTRIES (Continued)

Industry	NAICS	SIC	Sample Size	Description
Greenhouse B	111421	0181, 0811	156	Nursery and Tree Production
Soil Sterilization A	115112	0711, 0721	49	Soil Preparation, Planting and Cultivating
Soil Sterilization B	562910	1314, 1315	38	Remediation Services
Soil Sterilization C	562998	4959	114	All Other Miscellaneous Waste Management Services
Papaya Processing	115114	0723	227	Post harvest Crop Activities (Except Cotton Ginning)
Dried Fish and Fruit	311423	2034, 2099	38	Dried and Dehydrated Food Manufacturing
Fish Drying	311712	2077, 2092	56	Fresh and Frozen Seafood Processing
Ethanol/Biodiesel	325188	2819, 2869	86	All Other Basic Inorganic Chemical Mfg.
Lumber Kiln A	321114	2491	45	Wood Preservation
Lumber Kiln B	321999	2421, 2429, 2499	195	All Other Miscellaneous Wood Product Manufacturing
Research Center A	541710	3721, 8731, 8733	165	Research and Development in the Physical, Engineering and Life Sciences
Research Center B	611310	8221	564	Colleges, Universities and Professional Schools

Table F-1 shows the industries for which data were collected. NAICS (North American Industrial Classification System) and SIC (Standard Industrial Classification) correspond to numeric industry classifications provided by two services. Source: Risk Management Association Annual Statement Studies, 2004-2005.

TABLE F-2: INDUSTRY DESCRIPTIONS

NAICS	Description
424930	**Flower, Nursery Stock, and Florists' Supplies Merchant Wholesalers.** This industry comprises establishments primarily engaged in the merchant wholesale distribution of flowers, florists' supplies and/or nursery stock (except plant seeds and plant bulbs).

TABLE F-2: INDUSTRY DESCRIPTIONS (Continued)

NAICS	Description
115112	**Soil Preparation, Planting and Cultivating.** This U.S. industry comprises establishments primarily engaged in performing a soil preparation activity or crop production service, such as plowing, fertilizing, seedbed preparation, planting, cultivating, and crop protecting services.
562910	**Remediation Services.** This industry comprises establishments primarily engaged in one or more of the following: (1) remediation and cleanup of contaminated buildings, mine sites, soil or ground water; (2) integrated mine reclamation activities, including demolition, soil remediation, waste water treatment, hazardous materials removal, contouring land and revegetation; and (3) asbestos, lead paint and other toxic materials abatement.
562998	**All Other Miscellaneous Waste Management Services.** This U.S. industry comprises establishments primarily engaged in providing waste management services (except waste collection, waste treatment and disposal, remediation, operation of materials recovery facilities, septic tank pumping and related services, and waste management consulting services.
115114	**Post Harvest Crop Activities (except Cotton Ginning).** This U.S. industry comprises establishments primarily engaged in performing services on crops, subsequent to their harvest, with the intent of preparing them for market or further processing. These establishments provide post harvest activities, such as crop cleaning, sun drying, shelling, fumigation, curing, sorting, grading, packing, and cooling.
311423	**Dried and Dehydrated Food Manufacturing.** This U.S. industry comprises establishments primarily engaged in (1) drying (including freeze-dried) and/or dehydrating fruits, vegetables, and soup mixes and bouillon and/or (2) drying and/or dehydrating ingredients and packaging them with other purchased ingredients such as rice and dry pasta.
311712	**Fish and Frozen Seafood Processing.** This U.S. industry comprises establishments primarily engaged in one or more of the following (1) eviscerating fresh fish by removing heads, fins, scales, bones, and entrails; (2) shucking and packing fresh shellfish; (3) manufacturing frozen seafood and (4) processing fresh and frozen marine fats and oils.
325188	**All Other Basic Inorganic Chemical Manufacturing.** This U.S. industry comprises establishments primarily engaged in manufacturing basic inorganic chemicals (Except industrial gasses, inorganic dyes and pigments, alkalies and chlorine and carbon black).

Table F-2: INDUSTRY DESCRIPTIONS (Continued)

NAICS	Description
321114	**Wood Preservation.** This U.S. industry comprises establishments primarily engaged in (1) treating wood sawed, planed, or shaped in other establishments with creosote or other preservatives such as chromated copper arsenate, to prevent decay and to protect against fire and insects and/or (2) sawing round wood poles, pilings, and posts and treating them with preservatives.
321999	**All Other Miscellaneous Wood Product Manufacturing.** This U.S. industry comprises establishments primarily engaged in manufacturing wood products (except establishments operating sawmills and preservation facilities, establishments manufacturing veneer, engineered wood products, millwork, wood containers, pallets, and wood container parts: and establishments making manufactured homes (i.e. mobile homes) and prefabricated buildings and components)
541710	**Research and Development in the Physical, Engineering, and Life Sciences.** The industry comprises establishments primarily engaged in conducting research and experimental development in the physical, engineering, and life sciences, such as agriculture, electronics, environmental, biology, botany, biotechnology, computers, chemistry, food, fisheries, forests, geology, health, mathematics, medicine, oceanography, pharmacy, physics, veterinary, and other allied subjects.
611310	**Colleges, Universities, and Professional Schools.** This industry comprises establishments primarily engaged in furnishing academic courses and granting degrees and baccalaureate or graduate levels. The requirement for admission is at least a high school diploma or equivalent general academic training. Instruction may be provided in diverse settings, such as the establishment's or client's training facilities, educational institutions, the workplace, or the home, and through correspondence, television, Internet, or other means.

Table F-2 provides detailed descriptions of the comparison industries identified in Table F-1. Source: Risk Management Association Annual Statement Studies, 2004-2005.

F.3 OBTAINING INDUSTRY AVERAGE DATA

Industry average financial information for all industries identified in Tables F-1 and F-2 were obtained from Risk Management Association Annual Statement Studies, 2004-2005 (RMA). The exception is for Industry 541710 *Research and Development in the Physical, Engineering and Life Sciences*. Data for Industry 541710 were obtained from the 2003-2004 issue of RMA. Data were collected for each industry identified in Table F-1 and F-2. RMA reports current and historical financial statement data by industry. As noted earlier, the data in these studies include an analysis of a number of firms in each industry. The number of firms in the sample varies by industry, in this case ranging from 38 to 564. RMA aggregates these firm data by the size of the firm based on the firm's sales and assets levels. In addition, historical data are provided based on the average of all firms without regard to firm size. Because the magnitude of operations undertaken in the park may be of varying, and currently unknown sizes, historical data were used. The historical time period covered was from April 1, 2004 to March 31, 2005 (April 1, 2003 to March 31, 2004 for Industry 541710).

F.4 ESTIMATED FINANCIAL STATEMENTS

Financial statement estimations were created based on a $1,000 equity investment (net worth) in the firm. From this figure, the total assets of the firm were estimated using RMA data. RMA reports the industry average portion of total assets obtained from net worth. Using this industry average figure, the total assets of the firm were estimated as follows.

$$Total\ Assets = \frac{Net\,Worth}{\Pr oportion\ of\ Total\ Assets\ Financed\ by\ Net\,Worth}$$

For example, where RMA reports the net worth in an industry to be sixty percent of total assets, the total asset estimation is:

$$Total\ Assets = \frac{\$1{,}000}{.6} = \$1{,}666.67$$

With a total asset estimate, the remainder of the balance sheet was computed by calculating the proportion of assets represented by each account category.

To estimate firm sales, information on the dollars of sales for each dollar of total assets utilized is required. RMA reports the sales to total assets ratio. RMA reports three levels of this ratio based on the financial condition of the firm. The median ratio was used in this study. Combining the total asset figure computed earlier with the industry sales-to-assets ratio information permits one to estimate sales as follows:

$$Sales\,To\,Total\;Assets = \frac{Sales}{Total\;Assets}$$

For example, in an industry where sales-to-total-assets were reported by RMA to be 3.1 and total assets have previously been estimated to be $1,666.67, the following sales estimate would be made:

$$3.1 = \frac{Sales}{\$1,666,67}$$

Solving the equation for sales provides a sales forecast of $5,166.67. From this sales estimate, the remaining income statement items are estimated based on industry averages reported by RMA. The resulting financial statements are presented in Table F-3.

F.5 <u>LIMITATIONS</u>

It is important to point out that the comparables methodology, and thus the results presented here, are subject to a number of limitations. First, most firms have characteristics of multiple industries. Defining a firm as a participant in a single industry, as was necessary here, can distort the true nature of the firm. These distortions may or may not be economically significant. These and other potential distortions may be of sufficient magnitude to change the end-users conclusions. As such, use of these statements is appropriate only for those knowledgeable about such matters.

A second limitation is that RMA ratios are computed based on national industry norms. The extent to which these norms are sensitive to geographic difference, particularly differences related to operating in Hawaii, are unknown. Significant geographical differences would bias the results reported here. Third, no two firms are the same. Comparison to industry averages ignores unique firm characteristics. These unique firm characteristics may result in an actual implementation resulting in significantly different figures than those presented here.

It should also be noted that the ratios provided by RMA, and thus the statements presented here, are estimated using historical data. The extent to which future performance will differ from historical data is unknown. Time series changes in industry behavior could impact the results presented here substantially.

Finally, the statements presented here are estimated or pro-forma financial statements. By their very nature, differences between these estimates and those experienced by a particular firm engaging in the businesses discussed here should be expected. Managerial preferences, natural disasters, unexpected operating expenses and a great many other issues can impact the reported results. These differences may or may not be economically significant. The only way to find out with precision how the financial statements would look is to engage in the businesses and observe the historical results of those businesses.

TABLE F-3: PRO-FORMA FINANCIAL STATEMENTS FOR EACH $1,000 OF EQUITY INVESTED

	Grnhse A	Grnhse B	Soil Strl. A	Soil Strl. B	Soil Strl. C	Pap. Proc.
Assets	N=156	N=143	N=49	N=38	N=114	N=227
Cash and Equivalents	$180.33	$298.01	$710.14	$147.34	$633.80	$280.00
Trade Receivables (Net)	$436.07	$860.93	$628.02	$1,106.28	$1,122.07	$680.00
Inventory	$947.54	$841.06	$652.17	$77.29	$122.07	$586.67
All Other Current Assets	$111.48	$82.78	$236.71	$202.90	$159.62	$223.33
Total Current Assets	$1,675.41	$2,082.78	$2,227.05	$1,533.82	$2,037.56	$1,770.00
Net Fixed Assets	$1,239.34	$847.68	$2,140.10	$640.10	$2,126.76	$1,280.00
Intangibles (Net)	$78.69	$119.21	$154.59	$77.29	$136.15	$56.67
All Other Non-Current Assets	$285.25	$261.59	$309.18	$164.25	$394.37	$226.67
Total Assets	$3,278.69	$3,311.26	$4,830.92	$2,415.46	$4,694.84	$3,333.33
Liabilities and Equity						
Short Term Notes Payable	$537.70	$562.91	$763.29	$202.90	$417.84	$480.00
Current Maturity of L.T. Debt	$140.98	$135.76	$318.84	$103.86	$319.25	$143.33
Trade Payables	$291.80	$596.03	$386.47	$396.14	$488.26	$483.33
Income Taxes Payable	$32.79	$16.56	$14.49	$12.08	$9.39	$6.67
Other Current Liabilities	$196.72	$268.21	$434.78	$236.71	$394.37	$366.67
Total Current Liabilities	$1,200.00	$1,579.47	$1,917.87	$951.69	$1,629.11	$1,480.00
Long-Term Debt	$770.49	$559.60	$1,652.17	$338.16	$1,380.28	$670.00
Deferred Taxes	$22.95	$13.25	$19.32	$14.49	$70.42	$20.00
All Other Non-Current	$285.25	$158.94	$241.55	$111.11	$615.02	$163.33
Net Worth	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00
Total Liabilities & Net Worth	$3,278.69	$3,311.26	$4,830.92	$2,415.46	$4,694.84	$3,333.33
Income Statement						
Sales	$5,573.77	$9,602.65	$8,695.65	$6,038.65	$9,389.67	$6,333.33
Cost of Goods Sold	$2,106.89	$6,126.49	$0.00	$0.00	$0.00	$0.00
Gross Profit	$3,466.89	$3,476.16	$8,695.65	$6,038.65	$9,389.67	$6,333.33
Operating Expenses	$3,026.56	$3,341.72	$8,504.35	$5,585.75	$8,553.99	$5,934.33
Operating Profit	$434.75	$134.44	$191.30	$452.90	$835.68	$399.00
Other Expenses	$195.08	$38.41	($26.09)	$48.31	$206.57	$88.67
Profit Before Taxes	$239.67	$96.03	$217.39	$404.59	$629.11	$310.33

TABLE F-3: PRO-FORMA FINANCIAL STATEMENTS FOR EACH $1,000 OF EQUITY INVESTED (Continued)

	Dry Fish A	Dry Fish B	Bio Fuels	Kiln A	Kiln B	Research Center A	Research Center A
Assets	N=38	N=56	N=38	N=195	N=45	N=165	N=564
Cash and Equivalents	$184.81	$193.77	$169.18	$209.23	$165.39	$444.19	$268.84
Trade Receivables (Net)	$496.20	$878.89	$833.84	$775.38	$603.05	$706.98	$106.16
Inventory	$888.61	$1,069.20	$571.00	$898.46	$834.61	$53.49	$8.56
All Other Current Assets	$88.61	$117.65	$39.27	$58.46	$58.52	$160.47	$63.36
Total Current Assets	$1,658.23	$2,259.52	$1,613.29	$1,941.54	$1,661.58	$1,365.12	$446.92
Net Fixed Assets	$658.23	$826.99	$1,114.80	$821.54	$712.47	$604.65	$803.08
Intangibles (Net)	$93.67	$103.81	$84.59	$138.46	$10.18	$113.95	$22.26
All Other Non-Current Assets	$121.52	$269.90	$208.46	$175.38	$160.31	$241.86	$440.07
Total Assets	$2,531.65	$3,460.21	$3,021.15	$3,076.92	$2,544.53	$2,325.58	$1,712.33
Liabilities and Equity							
Short Term Notes Payable	$402.53	$809.69	$353.47	$492.31	$493.64	$174.42	$34.25
Current Maturity of L.T. Debt	$55.70	$148.79	$129.91	$147.69	$96.69	$41.86	$20.55
Trade Payables	$369.62	$574.39	$513.60	$409.23	$312.98	$237.21	$54.79
Income Taxes Payable	$12.66	$34.60	$3.02	$6.15	$5.09	$11.63	$1.71
Other Current Liabilities	$207.59	$273.36	$211.48	$258.46	$188.30	$404.65	$126.71
Total Current Liabilities	$1,048.10	$1,840.83	$1,211.48	$1,313.85	$1,096.69	$869.77	$238.01
Long-Term Debt	$351.90	$467.13	$619.34	$560.00	$348.60	$295.35	$405.82
Deferred Taxes	$17.72	$13.84	$39.27	$9.23	$12.72	$13.95	$0.00
All Other Non-Current	$113.92	$138.41	$151.06	$193.85	$86.51	$146.51	$68.49
Net Worth	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00
Total Liabilities & Net Worth	$2,531.65	$3,460.21	$3,021.15	$3,076.92	$2,544.53	$2,325.58	$1,712.33
Income Statement							
Sales	$4,810.13	$9,688.58	$5,740.18	$7,692.31	$8,396.95	$4,651.16	$856.16
Cost of Goods Sold	$3,208.35	$7,760.55	$3,736.86	$5,576.92	$6,608.40	$0.00	$0.00
Gross Profit	$1,601.77	$1,928.03	$2,003.32	$2,115.38	$1,788.55	$4,651.16	$856.16
Operating Expenses	$1,332.41	$1,501.73	$1,635.95	$1,746.15	$1,267.94	$4,409.30	$785.10
Operating Profit	$269.37	$426.30	$367.37	$369.23	$520.61	$241.86	$71.06
Other Expenses	$101.01	$77.51	$74.62	$76.92	$25.19	$23.26	-$14.55
Profit Before Taxes	$168.35	$348.79	$292.75	$292.31	$495.42	$218.60	$85.62

Table F-3 shows pro-forma financial statements for each $1,000 of equity invested. The financial statements were estimated from data in Risk Management Association Annual Statement Studies (RMA), 2004-2005 and 2003-2004 editions. Adjustments were made in instances when data provided by RMA were rounded producing unbalanced statements. The adjustments required did not exceed 3/10 of one percent in any instance.

APPENDIX G
GEOTHERMAL DIRECT USE FUNDING SOURCES

APPENDIX G – GEOTHERMAL DIRECT USE FUNDING SOURCES

G.1 INTRODUCTION

Should a geothermal enterprise park become reality, it is likely that some of the businesses seeking to use geothermal heat in their operations will need financial assistance.

It is the purpose of this appendix to identify potential monies and financial incentives which can assist the creation of enterprises deemed feasible by the geothermal direct use study. The following businesses were identified as feasible:

- Production of biodiesel
- Greenhouse bottom heating.
- Potting media sterilization
- Lumber drying

Though all four enterprises are agriculture related, the categories of assistance have been broken into two separate groups: Biofuel funding sources and Agriculture funding sources. There is actually overlap between the two categories, but some of the biofuel tax incentives are specific to biofuels only. On the other hand, many of the agriculture funding sources are more general in nature and can be applied to each.

G.2 STATE AND FEDERAL BIOFUEL FUNDING SOURCES

G.2.1 State of Hawaii Biofuels Policy

Hawaii is one of the national leaders in providing both mandates and financial incentives for biofuels.

Mandates: Act 240 (SLH 2006) created an alternate fuel standard (AFS) for the State, with a goal of providing 10 percent of highway fuel demand from alternate fuels by 2010; 15 percent by 2015; and 20 percent by 2020. Hawaii's Renewable Portfolio Standard (RPS), established by Act 95 (SLH 2004), requires that 20 percent of net electricity sales come from renewable energy by 2020, and it includes biofuels as a renewable energy source. The RPS law also sets milestones of 10 percent by 2010 and 15 percent by 2015.

Financial Incentives: In support of these goals, the State currently provides a reduction in State and county fuels taxes for biodiesel: a weighted average of $0.26/gal. The State government also provides a procurement preference for biodiesel of $0.05/gal.

G.2.2 Federal Incentives for Biofuels

In addition to these State-level incentives and mandates, the federal government provides support for biofuels, including:

Federal Tax Credits: The federal Energy Policy Act of 2005 (EPACT 2005) created several tax credits for biofuels. Major incentives include a $1.00/gal agri-biodiesel credit that is set to expire in 2008, and a $0.10/gal production tax credit for small agri-biodiesel producers set to expire at the end of 2008.

Federal Grants: EPACT 2005 allows the Secretary of Energy to provide grants to merchant producers of approved renewable fuels. The grants are to assist the producers in building eligible production facilities.[1] There is $250 million appropriated for the grants for 2006 and $400 million for 2007. The solicitation for applications has not been issued to date.

[1] Production facilities are eligible for grant monies if they are located in the United States and use cellulosic or renewable biomass or waste feedstocks derived from agricultural residues, wood residues, MSW or agricultural byproducts. 42 U.S.C. §7545

Information taken from:

Biomass- and Biofuels-to-Power Recommendations pursuant to House Concurrent Resolution 195 (Session Laws of Hawaii 2006)

Prepared for the Hawaii Energy Policy Forum by Rocky Mountain Institute with support from the State of Hawaii Department of Business, Economic Development, and Tourism DRAFT *December 1, 2006*

G.3 STATE AND FEDERAL AGRICULTURAL FUNDING SOURCES

Both the State of Hawaii Department of Agriculture and the United States Department of Agriculture maintain websites containing a multitude of information and potential funding programs.

G.3.1 Hawaii Department of Agriculture Website

The State's Department of Agriculture website has information related to State and Federal funding sources and contact information:

http://www.hawaiiag.org/hdoa/financial.htm

Selected funding Information includes:

STATE AGENCIES FUNDING SOURCES:

- **HAWAII DEPARTMENT OF AGRICULTURE, AGRICULTURAL LOAN DIVISION:** The loan division provides an extensive loan program, including direct, insured and participation loans, to qualified farmers, aquaculturists, and food manufacturers.
- **HAWAII DEPARTMENT OF AGRICULTURE, MARKET DEVELOPMENT BRANCH**: The Market Development Branch promotional program funds, on a fifty/fifty basis, legally registered agricultural associations' generic promotional programs. Qualified applicants should demonstrate a good understanding of their industry and show how the financial assistance will help solve the industry's stated main problem, and finally how their promotional project will be evaluated.
- **OFFICE OF HAWAIIAN AFFAIRS** : OHA financial assistance program serves primarily the native Hawaiian community. Ag-related community-based projects targeting the native Hawaiian community may qualify for funding.

FEDERAL AGENCIES FUNDING SOURCES:

- **UNITED STATES DEPARTMENT OF AGRICULTURE (USDA)-RURAL DEVELOPMENT**: USDA Rural Development agency encompasses three services: Rural Business-Cooperative Service (RBS), Rural Housing Service (RHS) and Rural Utilities Services (RUS). The field offices at the state and local levels administer the programs. Most relevant to rural agribusiness is RBS, the mission of which is to build competitive rural businesses and cooperatives. There are also: (a) the USDA Rural

Development's Business & Industry (B&I) Loan program that has, so far, served aquaculture, nurseries, and forestry businesses, meat processing and distribution projects; (b) the Rural Development's rural Business Enterprise Grant (RBEG) funding, which has included agribusiness projects; and (c) the Rural Development's Intermediary Re-lending Program (subject to RD Instruction 4274-D), which also provides funding support.

- **USDA COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE (CSREES) GRANT-Western Region Sustainable Agriculture Research and Education**: The goal of this program is to encourage research and education projects designed to increase our knowledge of integrated plant and animal production systems. These practices should have both a site-specific and regional application that will, over the long-term, improve food sources, the environment, and efficient use of renewable resources, while also enhancing economic and social wellbeing.
- **SMALL BUSINESS INNOVATION RESEARCH PROGRAM (SBIR) GRANT**: This program invites science-based small business firms to submit research proposals for funding. Topic areas include: Forests and Related Resources; Plant Production and Protection; Animal Production and Protection; Air, Water and Soils; Food Science and Nutrition; Rural and Community Development; Aquaculture; Industrial Applications; and Marketing and Trade.
- **SMALL BUSINESS ADMINISTRATION (SBA)'s HAWAII DISTRICT OFFICE FINANCIAL ASSISTANCE REFERRAL (FAR) PROGRAM:** The Financial Assistance Referral Program allows participating banks' officials to refer creditworthy entrepreneurs to SBA for assistance. An SBA Economic Development Specialist of the Business Information and Counseling Center (BICC) will help the business owner prepare a viable and complete loan package. Still, the participating bank has to approve the SBA guaranteed loan.

G.3.2 United States Department of Agriculture Website

USDA's Building Better Rural Places website has a large list of funding sources and information links related to sustainability, farming, environment, food safety, and small business. Some of the material is dated.

http://attra.ncat.org/guide/index.html

According to the site, the "guide is written for anyone seeking help from federal programs to foster innovative enterprises in agriculture and forestry in the United States. Specifically, the guide addresses program resources in community development; sustainable land management; and value-added and diversified agriculture and forestry. Thus, it can help farmers, entrepreneurs, community developers, conservationists, and many other individuals, as well as private and public organizations, both for-profit and not-for-profit."

G.3.3 Sample Federal Grants

Due to the timeliness of Federal Grant submission requirements, it's almost impossible to cite specific grant opportunities with indefinite funding. Instead, sections of three current grants announcements are included as samples: the USDA Conservation Innovation Grants (Parts A and C) and the USDA discretionary grant opportunity: Rural Business Opportunity Grant (RBOG). Each of these grants appears to have potential for funding some aspect of a geothermal direct use venture:

Grant Title: Conservation Innovation Grants (Part A): National Natural Resource Concerns - FY 2007	Grant #: US3295A

Summary

Type of Grant: Federal	**Due Date: 02/02/2007**
Multipart Grant: Yes	Solicitation Date: 12/01/2006
Agency Name: US Department of Agriculture	Relevance: 2
Office: Natural Resources Conservation Service (NRCS)	**Match Required:** Yes
CFDA: 10.912	**Actual Funds**: $20,000,000
	Actual Funds Type: Estimated

Summary:

The purpose of this program is to stimulate the development of conservation approaches and technologies in agricultural production. Program funding is intended to develop, test, implement, and transfer innovative and commercially viable farm and ranch conservation technologies that will facilitate the maintenance, restoration, or enhancement of natural resources on primarily agricultural lands without decreasing production on those lands.

Projects under this component should involve creative strategies to conserve one or more of the following natural resource concerns:

- **Bio-based energy opportunities**

Grant Title: Conservation Innovation Grants (Part C): National Technology - FY 2007	Grant #: US3295C

Summary

Type of Grant: Federal	**Due Date: 02/02/2007**
Multipart Grant: Yes	Solicitation Date: 12/01/2006
Agency Name: US Department of Agriculture	Relevance: 2
Office: Natural Resources Conservation Service (NRCS)	**Match Required:** Yes
CFDA: 10.912	**Actual Funds**: $20,000,000
	Actual Funds Type: Estimated

Summary:

The purpose of this program is to stimulate the development of conservation approaches and technologies in agricultural production. Program funding is intended to develop, test, implement, and transfer innovative and commercially viable farm and ranch conservation technologies that will facilitate the maintenance, restoration, or enhancement of natural resources on primarily agricultural lands without decreasing production on those lands. This program component is intended to support projects that will field test, evaluate, implement, or demonstrate specific technologies within specific needs areas identified by the funding agency.

Projects under this component will involve innovative technologies that will address:

- **Improved Energy Efficiency, which may involve: Wind power, solar power, and other renewable energy sources**

Grant Title: Rural Business Opportunity Grant (RBOG) Program (Part A): Non-Earmarked Funds - FY 2007	Grant #: US1336A

Summary

Type of Grant: Federal	**Due Date: 03/30/2007**
Multipart Grant: Yes	Solicitation Date: 12/08/2006
Agency Name: US Department of Agriculture	Relevance: 2
Office: Rural Business-Cooperative Service (RBS)	**Match Required:** Recommended
CFDA: 10.773	**Actual Funds**: $2,970,000
	Actual Funds Type: Estimated

Summary:

The purpose of this program is to support projects that will improve the economic conditions in rural areas throughout the United States. Program funding is intended to promote rural economic development through the provision of technical assistance, training, and planning to stimulate rural business and economic development.

Successful applicants will receive assistance for such activities as:

- **Identification and analysis of business opportunities that will use local rural materials or human resources**;
- **Identification, training for, and provision of technical assistance to existing or prospective rural entrepreneurs and managers;**

Information taken from: eCivis