CALIFORNIA
ENERGY
COMMISSION

IDENTIFYING NEW OPPORTUNITIES FOR DIRECT-USE GEOTHERMAL DEVELOPMENT

CONSULTANT REPORT

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Executive Summary

This report identifies opportunities for the most economically viable, near-term applications of geothermal direct-use in California today. In order to provide a list of projects, several steps were taken. First, direct-use applications were assessed for their potential to be implemented in the near-term (next five years). A review of geothermal resources in California was also completed and areas of the State were assessed for their potential for fostering new development.

The next step taken was to identify potential geothermal direct-use projects. This was done through both a literature search and an extensive number of interviews with direct-use experts, users and potential users. A list of 17 potential projects was developed. This list was narrowed to 10 projects with the most potential for near-term development, for which detailed assessments were completed. Using this information, the 10 top-rated projects were ranked for their feasibility and likelihood that they will be developed in the next five years.

Geothermal Direct-Use Applications

Geothermal direct-use in the past 20 years has enjoyed a moderate growth of over 150 percent. As of 2000, the total energy displaced by direct-use projects in the United States is estimated to be 8.35 x 10^{12} Btu/yr.[1] The use of low-to-moderate temperature geothermal resources for direct-use can be categorized into five major applications: aquaculture; pools and spas; space/district heating; greenhouses; and industrial processes.

Aquaculture

Aquaculture is the farming of animal and plant products using an aqueous environment. Algae (as a food supplement) and many fish and shellfish are raised on farms in California and throughout the U.S. Many of the farmed species grow faster and larger in warmer-than-ambient water. Geothermal fluids can be used to control the temperatures of the aquaculture facilities to produce larger and faster growing fish and also to allow production in the winter when it would otherwise not be possible.

Geothermal aquaculture really has no economically competitive energy alternatives. If a farm wants to grow a certain species in a certain climate, only a geothermally heated farm can provide low-cost, dependable hot water that increases the growing rate and can keep the commodity alive during the winter. Heating with natural gas or propane is not cost competitive.

There are approximately 17 geothermal aquaculture operations in California.[2] In total, these farms produce around 10 million pounds of fish per year.[3] Aquaculture has been the fastest growing application for geothermal direct-use for the past 10 years. However, for there to be substantial growth in geothermal aquaculture, there needs to be an expansion in aquaculture of new species, since growth in the farming of existing species seems to have leveled out in their market demand.

Spas and Pools

There are three major types of mineral and geothermal waters in the U.S.: hot springs resorts with hotel-services and accommodations, commercial plunges or pools and soaking tubs with camping facilities and food service, and the primitive undeveloped spring without any services.[4]

Today, there are about 60 sites using geothermally heated water in spas and pools in California.[5] Geothermally heated spas don't really have an alternative energy source, as the attraction is that the water is geothermally heated.

Growth of resorts and pool applications was essentially zero from 1995 to 2000 in California and the U.S.[6] This halt in growth is most likely due to more health and environmental regulations. In the past, health departments have allowed existing resorts and hot springs to operate with the geothermal waters continuously flowing through the spas without treatment. These "flow through" pools and surface disposal of effluent are typically no longer permitted. Growth in the uses of geothermal heating for resorts, pools, and spas is not forecast for the future in California.[6]

Space and District Heating

Geothermal energy for space heating of residential, commercial and institutional buildings has a strong potential in California.[7] Space heating is provided by using geothermal fluids to heat air in buildings and homes. District heating is the implementation of space heating throughout several buildings or a community through a network of pipes carrying heated water originating from one to several production wells. There are currently more than 25 geothermal space heating and 5 district heating applications in California.[2]

The economic viability of a potential geothermal space heating application depends upon whether payback can be achieved within an acceptable period of time. Although such an analysis is necessarily complex and site specific, several analytical tools are available to simplify the process, including software for analyzing energy demand and economic constraints [85, 86]. A complete economic analysis will include consideration of the quality and accessibility of the local geothermal resource, the size of the building or buildings to be heated and their likely energy demand, whether retrofitting of a facility is necessary, the cost of utilizing local energy alternatives and the respective operations and maintenance costs, etc. An example of how such an exercise was recently provided by Rafferty [6], who undertook a simple analysis of a generic hypothetical site at which a 1,000 foot borehole provided access to a geothermal resource. That simple analysis showed that, in that hypothetical instance, a newly built building in excess of 100,000 square feet would be required to achieve a 5 year payback. If retrofitting of the building were required, the minimum building size increased to 225,000 square feet. This analysis also showed, however, that the payback period is strongly affected by the drilling requirements – a shallower borehole would significantly diminish the minimum building size. These results emphasize the importance of conducting a thorough site specific analysis in order to assess the economic realities of a potential geothermal space heating application.

The use of geothermal space heating is accelerating, relative to other geothermal applications. The absolute growth rate of geothermal space heating of buildings has been constant from 1995 to 2000 at 2 percent.. The opportunities for new space heating and district heating projects are most attractive for large, public-sector building projects and new, dense cluster, owner occupied construction in the public and private sectors.

Greenhouses

Geothermal greenhouse heating is one of the most popular geothermal direct-use applications. It is both economical and efficient compared to conventional fuel heating. Geothermal space heating in greenhouses extends the growing season and increases the rate of growth for plants in commercial markets.

Geothermal greenhouse growth and heating are two of the most recognized direct-use applications with the greatest potential for expansion of existing and new applications.[6] Growth from 1995 to 2000 has been nine percent annually in the U.S. Currently there are six geothermal greenhouse applications in California growing roses, cut flowers, potted plants, and vegetables. Growth in the geothermal greenhouse sector takes place predominately in large multi-acre operations, although the majority of the industry is comprised of small individual businesses less than 2 acres.

Industrial Processes

Because of high heating loads, there are numerous industrial applications for which geothermal energy could be appropriate (Figures 1 and 2). Unfortunately its appeal has not translated into a large number of applications. One explanation for this is that some industrial process heating requirements require steam at 250°F or higher.[6] This temperature is outside the range usually considered direct-use, which typically utilizes low-to-moderate temperature geothermal fluids of 90°F to 200°F.

In the U.S., the most common geothermal direct-use applications for industry include enhanced oil recovery, zinc extraction, and food processing.[8] Energy sources competing with geothermal direct-use for most industrial applications include heat recovery from the main processes and conventionally fueled boilers or heaters.

Prospects of Applications for Near-term Expansion

Generic geothermal direct-use applications were ranked for their potential for growth from new or expanded operations in California in the near-term. Because many of the ranking criteria utilize data and knowledge gained from existing applications, the results reflect the relative economic success of these existing applications. Aquaculture was ranked as the generic application with the greatest potential for expansion, followed by greenhouses, space heating/district heating and spas and pools. Industrial applications ranked last. Aquaculture received a score of 64 (a lower score has a higher potential), followed by greenhouses (70), space heating/district heating (74), spas and pools (75) and industrial applications (79).

Geothermal Resources

California has significant geothermal resources throughout the state. Almost 1,000 thermal wells and springs, more than 900 low-to-moderate temperature geothermal resource areas and over 100 direct-use sites have been identified in California.[9] Six percent of the state's electricity is supplied by geothermal power plants using high-temperature resources. The Geo-Heat Center in the Oregon Institute of Technology states that there are nearly 1,500 potential geothermal well sites located within five miles of towns and medium-sized cities in the western U.S. Low-to-moderate temperature resources have an energy base of 38,900 quads (a quad is 10^{15} Btu) compared to high-temperature geothermal resources which have a resource base of 4,800 quads in the US.[8] A list of all known geothermal resources in California is included in Appendix 3.

To create a manageable search effort of this report, California was divided into 5 major geothermal regions. Those regions were rated for their potential to foster new direct-use developments. The top three regions, Region C – Sierra Cascades, Region D - Imperial Desert, and Region E – South Coast, encompass most of the geothermally active areas of eastern and southern California.

Identified Potential Geothermal Projects

Seventeen projects that are in various stages of realization were identified for analysis through extensive literature search and interviews. These 17 were selected from a much larger number of in-progress or completed projects. Those chosen provide the broadest possible range of considerations that influence the likelihood of success of the various types of geothermal direct-use applications. This analysis develops information on the likelihood for near-term development. Additional information was collected on the top-rated projects, and an in-depth analysis and ranking was completed for them. The 17 identified projects are:

Mineral Extraction from Geothermal Brine

The CalEnergy Corporation currently operates a facility to extract zinc from geothermal brine at their Imperial Valley geothermal power plant. The California Energy Commission has also supported a study of the extraction of manganese from geothermal brine. This report considers manganese extraction to have strong potential for near-term development, along with the extraction of lithium and boron at these facilities.

Aquaculture and Greenhouse Heating in Canby, CA

I'SOT, Inc. in Canby, is planning to build a small geothermal electricity generation facility for their community. Warm water resources should be also available for aquaculture and greenhouse heating projects. If the geothermal-electric facility is built, I'SOT, Inc. has identified an aquaculture operator who would like to expand to use the geothermal waste heat. I'SOT, Inc. would also like to pursue a partnership with a greenhouse operator to which they could provide warm water for greenhouse heating. This report has concluded that if I'SOT, Inc.'s geothermal electricity generation facility is built, both aquaculture and greenhouse heating would be feasible. I'SOT, Inc. uses geothermal fluids to heat more than 50,000 square feet of residential and commercial building space in Canby.

Direct-use in The City of Paso Robles

As the result of a recent earthquake, a significant geothermal spring has formed in the parking lot of the City of Paso Robles City Hall. The Energy Commission is co-funding a project with the City to determine a proper disposal method for the warm water from the new spring as well as implementing potential direct-use applications using this resource. There is potential for near-term implementation of such projects.

Mammoth Lakes District Heating Project

A geothermal district heating project in Mammoth Lakes would use either waste heat from the nearby Casa Diablo power plant or drill a production well close to the community for space heating and snow-melting. The proposed first phase of this project would provide space and water heating to large public customers located close to a geothermal distribution system at the Mammoth Community Water District (MCWD) facilities. A recent feasibility study completed by FVB Energy concluded that such a project could be feasible if an appropriate geothermal resource could be developed on or near the MCWD facilities.[10]

Salton Sea Restoration – Geothermal Desalination

Geothermal-driven desalination is being considered as an option to restore the Salton Sea to an ecosystem that can continue to serve as wildlife habitat. Without restoration and with an ever-increasing salinity level, the Salton Sea is not expected to remain as a habitat for fish, birds and other wildlife. included. There are economic and political barriers to a geothermal-driven desalination project, but it remains one that could be implemented in the near future.

Space Heating for Four California Military Facilities

A 2003 report, Geothermal Energy Resource Assessment on Military Lands[11], examined the possibility of developing geothermal utility-grade electricity production and direct-use on military facilities. The report identified four military facilities in California with potential for direct-use heating, and completed basic engineering and economic assessments. There were several unknown factors for these projects, such as the potential load, interest on the part of facility operators in implementing direct-use, and the likelihood that appropriate geothermal resources could be developed to support space heating. This report found that if those unknown factors could be addressed, space heating could be feasible for one of four facilities, the Sierra Army Depot near Herlong in Northern California.

New Spa Construction in Desert Hot Springs

According to the Department of Conservation, Division of Oil, Gas & Geothermal, there have been recent permit applications for new direct-use spa projects in the Desert Hot Springs area.

Triple Use at Heber Geothermal Power Plant

This project involves the direct-use of hot water effluent from a Heber geothermal power plant. This water is warm enough and of sufficient quality to use in aquaculture ponds. The surrounding area is agriculture, where waste water from aquaculture operations could be used for irrigation.

Algae Farm Pond Heating

Earthrise Nutritionals operates an algae farm in the Imperial Valley. The algae are used for nutritional supplement products marketed by Earthrise. Currently, the operations have to be suspended during the winter due to temperatures that are too cold to sustain algae growth in their ponds. However, it is possible that geothermal fluids could be used not only for heating of those ponds to allow year-round operation, but foster growth with the high levels of carbon dioxide common to geothermal waters.

Direct-use in the City of Twentynine Palms

A past Energy Commission-sponsored project supported the assessment of geothermal resources within the Twentynine Palms area. A potential resource was discovered through test drilling; however, no use of such resources has been implemented.

Huntington Beach Direct-use of Oil Processing Wastewater

An Energy Commission-sponsored project in the 1980's studied the potential for using hot water effluent from oil processing operations in the area for direct-use applications. The report concluded there was potential; however, no further action was ever taken on those results.

Geothermal District Heating in Bridgeport, CA

A geothermal district heating system for the town of Bridgeport, CA was studied with support from the Energy Commission in the early 1980's[12]; however, a test well that was drilled was found to be unable to support the project. There is seemingly little interest now in geothermal district heating for the community and this report has concluded that this project has little potential.

Expansion of Direct-use at the San Bernardino Wastewater Treatment Plant

The San Bernardino Water Department uses geothermal energy for district heating and other direct-use applications in the City of San Bernardino. One of the additional direct-use applications includes an Energy Commission-sponsored project from the early 1980's which provides heat for wastewater treatment processes. At that time, one of three potential geothermal applications in the wastewater treatment facility was implemented, with expectation that the other two would be implemented shortly. However, today there is no plan to expand geothermal direct-use in their wastewater treatment facilities. The San Bernardino Water Department continues to operate their district heating system and has the potential to take on new customers.

Project Ratings

To determine which projects have the highest potential for near-term development, those identified in this report went through two series of ratings. Initial ratings identified 10 projects for which detailed assessments were justified. For those 10 projects, additional information was gathered and engineering and economic assessments were completed. The 10 projects were ranked according to the economic assessments. The five geothermal direct-use projects with the strongest potential for near-term development are shown in Table 1.

Table 1 Final Rankings of Top Five Projects

Projects	Final Score (max=40)	Ranking
Mineral Extraction from Geothermal Brine	**39**	**1**
Aquaculture in Canby, CA	**34**	**2**
Greenhouse Heating in Canby, CA	**25**	**3**
Direct-use in Paso Robles, CA	**23**	**4**
Mammoth Lakes District Heating	**22**	**5**

Several factors, developed through the research conducted for this report, were found to positively influence the likelihood of near-term development of geothermal direct-use projects and were used to form final project rankings. These factors are:

- The availability of geothermal resources, including methods to dispose of geothermal fluids
- Expertise in direct-use geothermal and its use in the applicable industry
- A desire to implement direct-uses
- A "hero" who is sufficiently invested to push a project through regulatory hurdles
- Past direct-use experience, especially with similar applications, at the site and by the parties involved
- Cost savings compared to alternatives of choice in local areas
- Ability to meet the economic requirements imposed on the project
- Ability to overcome political and bureaucratic barriers

Recommendations

Several recommendations are made to the Energy Commission based on the conclusions in this report. These recommendations are:

- The Energy Commission can foster the top-ranked projects included in this report by considering the following:
    - For the Mineral Extraction project, continued involvement by the Energy Commission could help expand extraction operations to include boron and lithium as well as zinc and manganese.
    - For the direct-use projects in Canby, the Commission could encourage the development of a small geothermal electric plant for the I'SOT community, which would provide the opportunity for multiple direct-use applications.
    - For the direct-use project in Paso Robles, the Commission is already providing assistance to mitigate the impact of the recently formed geothermal spring in the center of the City. This involvement may help to implement other direct-use application(s) for the new spring.
    - For the District Heating project in Mammoth Lakes, the development of a resource in or near the community would greatly improve the outlook for geothermal district heating. Involvement by the Commission would encourage these developments.
    - For the Salton Sea Geothermal Desalination for Restoration project, the Commission cannot currently play a significant role in the needed restoration. However, involvement in the smaller desalination test facility could provide benefits not only to the restoration project, but to other possible desalination projects in the State with geothermal resources.
    - For the Military Facility Space heating projects, the Commission could work with the military to develop direct-use applications on military facilities. Specifically, the Sierra Army Depot facility may have potential for space heating, but more information needs to be collected.

The Commission could:

- Continue assessing the potential of projects identified in this report. The status of such projects may change and involvement by the Commission could result in more geothermal direct-uses in the State.

- Reduce bureaucratic barriers to geothermal direct uses. The Energy Commission could provide benefits if the complaints of users described in this report are addressed. Working with other agencies in California to promote direct-use and ease the difficulties of implementing such projects could have strong effects on the industry.

- Conduct further studies on direct-use applications that have strong potential but low levels of implementation in the State. The Energy Commission could specifically address the low levels of greenhouse heating in California. This report, and several direct-use experts, has concluded that greenhouse heating has strong potential for growth. There are very few actual applications in the state, but further study of the industry could result in increased growth.

Overview

This report focuses on steps taken to determine the most economically viable near-term applications of geothermal direct-use in California.

Geothermal Direct-Use Applications – discusses the major generic applications of direct-use, non-electric geothermal energy and their prospects.

Geothermal Resources – discusses the geothermal resources available in California. In this section, California is geographically divided into five major geothermal regions ranked for the likelihood of implementing geothermal direct-use projects. It explains the criteria used to rank these regions, and other pertinent information on direct-use resources.

Review of Potential Geothermal Projects – discusses 17 potential projects and provides engineering and economic assessments for the 10 most likely projects.

Conclusions – provides recommendations for steps that can foster geothermal direct-use in California.

Appendices – includes data used for rankings compiled in this report, as well as data on geothermal resources in California that could be useful to parties interested in developing them. This data is provided in a format that can be easily included in Department of Forestry Geographic Information System (GIS) software. An overview of interviews completed for this report is also included.

Introduction

This report identifies opportunities for the most economically viable near-term applications of geothermal direct-use in California today. The introduction lays out the basics of geothermal energy: definitions, origins, characteristics, availability, applications, usage growth, and advantages or disadvantages compared to other energy resources.

Origin of Geothermal Energy: The Geology

Geothermal energy is the natural heat from the earth. The principal source of this heat is radioactive decay of naturally occurring isotopes [14]. At the core of the Earth, 4,000 miles below the surface, temperatures can reach 9,000°F.[13] The resulting temperature gradient from the core to the surface results in a continuous transfer of heat to the Earth's outer layers. Heat flow to the Earth's surface, however, is not uniformly distributed. Through a variety of geological processes, the local heat flow may be substantially increased or decreased, relative to the global average heat flux. As a result, in many instances, water that flows into the earth can get heated by relatively hotter porous rock below. If water flow is in the vicinity of magma bodies, such as the Geysers, Coso, Long Valley, and the Salton Sea, the water may be sufficiently heated to result in boiling or the formation of super-heated steam. However, the majority of geothermal resources are the result of ground water flowing in fault zones or in aquifers that allow deep circulation. Sometimes the heated ground water comes to the surface in a natural hot water spring. More often, a well is drilled to tap the underground resource to bring hot water to the surface.[15] In the section, Geothermal Resources, a map indicates where geothermal energy has been located in California.

Types and Characteristics of Geothermal Energy

Geothermal energy is classified into types: low-to-moderate temperature resources with hot water below 350 °F, and high-temperature resources with water above 350 °F. Low-to moderate temperature resources are the most common.[7] High-temperature resources can flash to steam when influenced by atmospheric pressure. Geothermal energy may also be found as heated sub-surface rock without any water. This type of geothermal energy is known as hot dry rock. This report focuses on low-temperature resources that can be used in direct-use applications. Direct or non-electric use of geothermal energy refers to the immediate use of geothermal heat energy rather than to its conversion to some other form such as electricity.

Availability of Geothermal Energy

The prevalence geothermal direct-use (low-to-moderate temperature) resources is widespread in California. Geothermal hot springs are found throughout California and in almost every county. Approximately 46 of the state's 58 counties have known resources. Almost 1000 thermal wells and springs, more than 900 low-to-moderate temperature geothermal resource areas and more than 100 direct-use sites have been identified in the state.[9] In California, 6 percent of the state's electricity is supplied by geothermal power plants using high-temperature resources. The Geo-Heat Center in the Oregon Institute of Technology states that there are nearly 1,500 potential geothermal wells located within five miles of towns and medium-sized cities in the western U.S. Low-to-moderate temperature resources have an energy base of 38,900 Quads compared to high-temperature geothermal resources which has a resource base of 4,800 Quads in the US.[8]

Uses for Geothermal Energy

High-temperature geothermal resources are an economic alternative for generating electricity and for industry process heat. In contrast, direct-use is the application of low-temperature geothermal resources in the form of hot water. A geothermal reservoir can be developed by conventional water well drilling equipment. Low-temperature resources (the focus of this study) are primarily used for space heating of residential and commercial buildings, agricultural & commercial greenhouses, food processing facilities, and in aquaculture farms.[16] The later section, Geothermal Direct-Use Applications, provides more detail on direct-use applications. One of the major applications is for ground source heat pumps (geothermal) systems. This type of application is so widespread (59 percent of the geothermal energy use in the U.S.) that it is covered by other studies and thus is not included in this project's scope.[7]

Growth in the Use of Geothermal Energy

Geothermal direct-uses in the United States have been growing. Traditionally, direct-uses have been on a small scale and almost solely by individuals. More recently, larger-scale developments for district heating, greenhouse complexes, and major industrial use have occurred.[1] In 1975, the combined use of geothermal direct-use for space heating, greenhouses, aquaculture, industrial use, and resorts and spas was less than 1000 GigaWatt-hours/year (GWh/year). In 1994, usage had risen to over 4000 GWh/year.[7] Geothermal space heating of homes, schools and businesses has been in place for over 100 years.

Advantages of Geothermal Energy

Geothermal energy has advantages in its dependability, security, high energy efficiency and low environmental impacts, including low to nil carbon emissions, compared to competing energy sources. However, growth of direct-use geothermal applications has encountered some barriers related to technological and economic challenges.

Cost and Availability

Low temperature geothermal resources can supply heating without the price volatility associated with traditional fuels. It is also much less expensive than using traditional fuels. Savings of as much as 80 percent over fossil fuels are reported.[17] Geothermal energy is a domestic resource, which adds to our nation's energy security, decreases our trade deficit, and allows the use of petroleum for higher priority uses. Compared to other renewable resources such as wind and solar, geothermal energy output is not cyclical. Its output is constant and thus does not require storage strategies for its use. Low-temperature resource uses are environmentally friendly.

Environmental Impacts

Direct-use of geothermal energy has low environmental impacts. Very little or none of the air pollutants produced by burning fossil fuels - such as carbon monoxide, oxides of nitrogen, sulfur oxides, and unburned hydrocarbons - are emitted. Application of geothermal energy will reduce the creation of gaseous air pollutants and acid rain by reducing the combustion of fossil fuels. Geothermal direct-use also has virtually no emissions of greenhouses gases and zero thermal pollution.[8]

Reliability

Geothermal resources are immune from intermittency and do not require refueling. As a result, they represent the most stable energy resource available. In addition, this energy source is immediate and local, allowing it to be insulated from political and economic instabilities that can affect other energy production methods that rely on an intact and responsive physical, economic, and political infrastructure. The geological framework requires no maintenance and, for most low-temperature applications, will not degrade over time. Operation and maintenance costs are usually lower than other competing energy sources. Where studies have been conducted, direct use applications often have availability values in excess of 90 percent [85].

Challenges to Geothermal Energy Usage

Resource Development

The most distinct challenge faced by geothermal direct-use is that it must be used on-site. It cannot be piped over long distances. Therefore, the resource and the users must be co-located.

Other barriers to faster expansion of geothermal direct-use have been: a lack of information about the resources, which have been overlooked by large developers who are more interested in high–temperature geothermal for electricity production; a lack of architects, engineers, drillers and construction companies who are trained in direct-use technologies and applications, and willing to capitalize on them; and the perception of relatively high risk and high initial cost of producing geothermal resources. In addition, whether direct use applications favorably compete with conventional fuels varies from place to place, depending upon the local energy supply infrastructure and prevailing market forces. That variability has made it difficult to develop simple cost comparisons for evaluating energy use options. Even so, the increasingly volatile fossil fuel energy market makes it likely that this barrier will not persist.

Regulations

Several direct-users of geothermal have admitted that dealing with regulatory agencies can be difficult and can involve working with multiple government agencies. This can even be difficult for an experienced geothermal developer, let alone someone with very little experience. The process of getting proper permitting for resource development, disposal and leasing has been getting more expensive and time consuming. Tighter regulations on geothermal well development have been making systems more expensive in order provide protection to the environment.

In the past, gaining access to public lands for geothermal development has been difficult. Recent changes, however, may allow easier access to the significant geothermal resources located on public lands. In 2001, it became National Energy Policy that the government "re-evaluate access limitations to public lands in order to increase renewable energy production, such as biomass, wind, geothermal, and solar."[18] It was also stipulated that regulators "determine ways to reduce the delays in geothermal lease processing".[18] This has led the way for federal agencies to make it a priority to increase access to public lands for geothermal energy development. Though barriers exist that will slow the adoption of these guidelines, hopefully increased access to public lands should facilitate the expansion of geothermal direct-use.[19] These access issues pertain mainly to geothermal power production; however some impacts on direct-use projects can be expected.

Competing Energy Sources

Feasibility of using geothermal resources in a given application must be beneficial and provide energy at a lower cost than the next best alternative. Once in place, a geothermal energy system will not be subject to the fluctuating costs of fuel prices that are common to other energy sources. Geothermal direct-use projects tend to have higher capital costs than their alternatives (though not always); therefore the annual savings resulting from the use of geothermal energy must be large enough to repay such increases in capital investment. Life-cycle costs can be favorable for geothermal projects. The energy alternatives to the direct-use of geothermal resources are typically electricity, natural gas, and propane. However, these alternatives are not always available and their availability will be a significant consideration when choosing to implement a geothermal direct-use application.

Currently, initial capital costs for using electricity are commonly lower than that of geothermal. However, evolving technology is reducing capital costs for direct-use equipment and increasing its efficiency, making it increasingly cost competitive even for first costs. In addition, annual energy costs of using electricity as a heat source is typically higher than geothermal sources. Electricity prices for California utilities are shown in Table 17 of Appendix 1. The Energy Commission's 2002-2012 Electricity Outlook Report predicts that electricity rates for customers will "increase slightly every year until 2012". [20] Usually electricity will be an energy option in all areas of the state – except in very remote locations that have no connection to the distribution grid. In those areas, the cost of connecting to the electricity grid may be prohibitive and other sources of energy will be considered, including methods of generating electricity on-site.

Natural Gas is usually provided through a distribution piping system. Though a majority of the population in California is served with natural gas, there is a significant portion of the state that has no natural gas infrastructure or service. A map of natural gas service by major utilities is shown in Figure 12 in Appendix 1. If available, the capital costs of using natural gas as an energy source are typically lower than that of geothermal. The annual energy costs of using natural gas as a heat source are moderately higher than that of geothermal, but not as high as using electricity. However, according to the Energy Commission's Natural Gas Market Assessment, prices for natural gas will likely rise slightly faster than inflation. [21]

Propane is the alternative typically used when natural gas service is not locally available. Propane is usually stored on-site where storage tanks are refilled on a regular basis by a servicing company. Although the cost of using propane as a heat source usually resides somewhere between that of natural gas and electricity, variability across the state is high.

Goals of This Report

This report identifies geothermal direct-use projects in California that could be implemented in the near future. The tasks set forth to accomplish this goal are:

1) Complete an initial literature search and series of interviews to gather information on geothermal resources and direct-use applications in California;
2) Provide generic assessments of geothermal direct-use applications;
3) Provide an assessment of geothermal resources in California and select a minimum of three regions of California with the greatest potential for near-term direct-use development for review in this report;
4) Identify potential geothermal direct-use projects in the selected regions; and
5) Provide review and engineering/business assessments of projects with good potential and detailed review of identified potential projects.

The results of these tasks are provided in this report. The sections included in this report are:

GEOTHERMAL DIRECT-USE APPLICATIONS – discusses the major generic applications of direct-use, non-electric geothermal energy uses and their prospects for near-term new or expansion projects in California.

GEOTHERMAL RESOURCES – discusses geothermal resources available in California. California is divided into five major geothermal regions, ranked for their likelihood of fostering geothermal direct-use. This section includes data on the five regions, the criteria used to rank them, and other pertinent information regarding direct-use resources in California.

REVIEW OF POTENTIAL GEOTHERMAL PROJECTS – discusses potential projects identified through extensive literature search and interviews. An overview of 17 potential projects is provided as well as detailed assessments, including engineering and economic assessment where possible, of the 10 projects most likely to be developed.

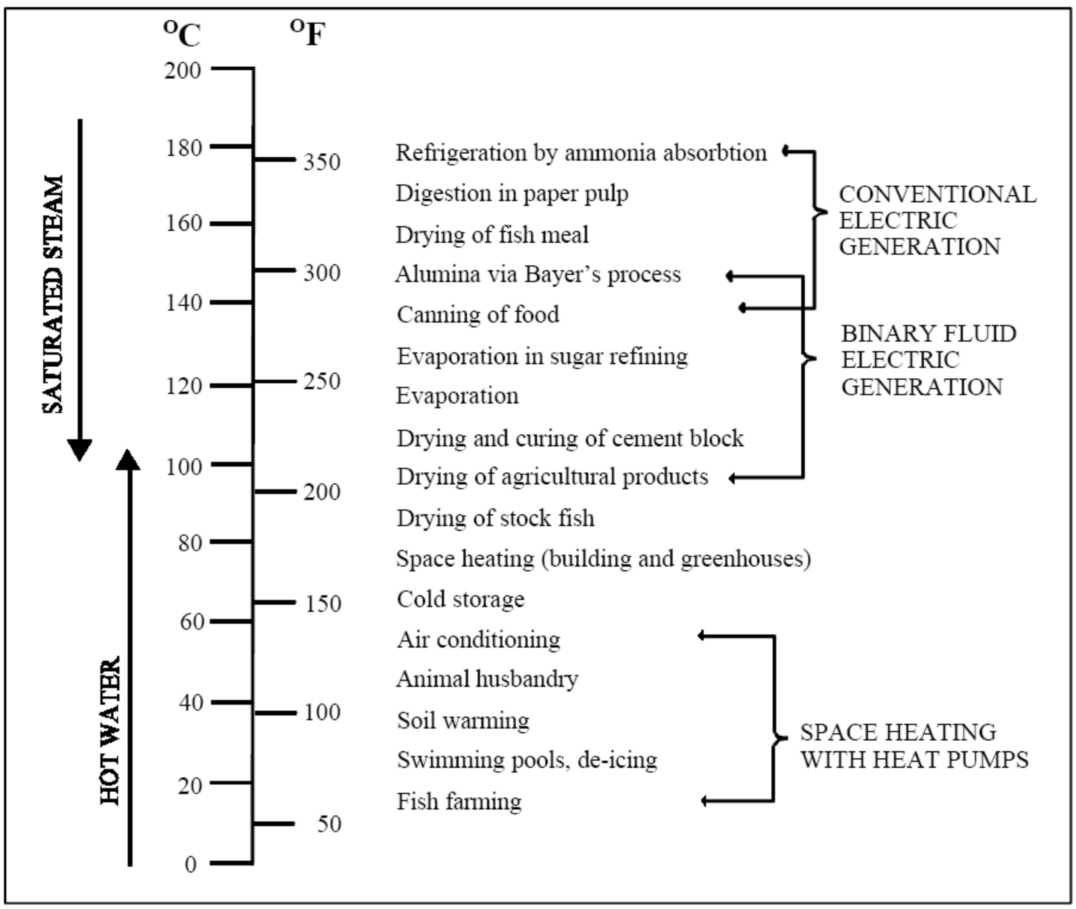
CONCLUSIONS – discusses the recommended steps that can be taken to foster geothermal direct-uses in California.

APPENDICES – includes data used for rankings compiled in this report, as well as data on geothermal resources in California that could be useful to parties interested in developing them. This data is provided in a format that can be easily included in Department of Forestry Geographic Information System (GIS) software. An overview of interviews completed in the process of compiling information this report is also included.

Geothermal Direct-Use Applications

This section discusses the major generic applications of direct-use, non-electric geothermal energy and their prospects for near-term new or expansion projects in California. This assessment is based on an extensive literature search and interviews with geothermal energy experts (Appendix 3). “Direct-uses” of geothermal energy refers to the immediate use (primarily for heating) of the heat energy contained in the hot water heated by the Earth. “Direct-uses” do not include applications where the geothermal energy is used in generating electricity. Figure 1 (the Lindal Diagram) summarizes the temperature requirements of various direct-use applications.

Figure 1 Lindal Diagram [1]



In order to utilize direct-use applications, the water from a hot water spring or well must be developed. A hot water spring, which brings hot water to the surface naturally may be the simplest and least expensive to utilize for heating. More often, a well has to be drilled either to bring the underground heated water to the surface, or to allow use of a downhole heat pump. Heat pump applications will not be further discussed in this report. For direct-use applications, which use low-to-moderate temperature resources, conventional water well drilling equipment can be used. [15]

Once at the surface, the hot water from the earth is typically pumped through a heat exchanger that transfers heat energy from the heated geothermal fluid (water) to the existing water supply or to the air. The heated water or air is then used for domestic water or space heating. The heat exchanger isolates the geothermal fluid from the geothermal heating equipment, which may be desired if the fluid contains sufficient concentrations of dissolved minerals that could cause corrosion, scaling or fouling of pipes, valves and other components in the geothermal heating application. Heat exchangers mitigate these problems. However, numerous examples are known in which the geothermal fluid is sufficiently dilute to allow use directly in the heating system.

The use of low-to-moderate temperature geothermal resources for direct-uses can be categorized into five major applications: pools and spas; space/district heating; aquaculture; greenhouses; and industrial processes.

Geothermal direct-uses in the past 20 years have enjoyed moderate growth (over 150 percent). As of 2000, the total energy displaced by direct-use projects in the US is estimated to be 8.35 x 10E12 Btu/yr.[1] Some of the reported sharp increases in direct-use in pools and spas is a result of more diligent data collection rather than growth in the sector. Removing the growth of pool and spa direct uses from 1995 to 2000, the compounded annual growth rate of direct-use is approximately 5 percent.[6] Experts believe that the geothermal direct-use energy in California has always been utilized in the past “and will continue to be” in the future. According to one expert, it “may not widely increase, but it will not decrease in use” either.[22]

Table 2 shows the distribution of direct-uses of geothermal energy in the U.S. Note that even though heat pumps are the largest user (59 percent), these applications are not part of this study. Heat pump applications are covered in other California Energy Commission and U.S. Department of Energy reports.

As shown in , typically we find that aquaculture, and spa and pool applications require the lowest temperature geothermal fluids (80°F/27^{o}C to 200°F/93^{o}C), space heating and greenhouse requirements are in the range of 105°F/47^{o}C to 200°F/93^{o}C, and industrial processes need the highest temperatures, over 200°F/93^{o}C. The following are short descriptions of these major generic applications, their requirements, geothermal energy alternatives, and existing applications in California.

Table 2 Distribution of Direct-use Geothermal Energy in the U.S. [1]

Direct-use Applications	Percent distribution of direct-use geothermal energy in the U. S.
Heat Pumps	59.1
Aquaculture	13.8
Spas and Pools	12.3
Space Heating	7.3
Greenhouses	5.6
Agricultural Drying and Industrial Processes	1.9
Snow Melting	0.08

Aquaculture

Aquaculture is the farming of food (fish and shellfish) and nutrients (e.g., algae) utilizing controlled water systems. Many fish and shellfish are raised on farms in California and throughout the U. S. Many species grow faster and larger in warmer (than ambient) water. Geothermal fluids can be used to control the temperature of the fish culture facilities to produce larger and faster growing fish and also allow fish production in the winter when it would otherwise not be possible. Many species of fish such as tilapia, catfish, and striped bass are raised in geothermally heated multi-acre ponds in California. Usually the geothermally heated water can be used directly in the ponds. This eliminates the need for heat exchange equipment. Pumps are required to produce the water. Most large growers have two to three wells for their operations. A few smaller operations depend on a single well for their farm.[3] For an aquaculture farm, water quality and water temperature are important. Typical water chemistry for a fish farm is[3]: 7.8 pH, 980 ppm Na, 46 ppm K, 132 ppm Ca, 33 ppm Mg, and 65 ppm SiO_3 (ppm is parts per million). Temperature is typically 145ºF. All of these as well as nitrogenous wastes from the fish and chlorine levels (from municipal water supplies) are water chemistry factors that can affect fish growth.[23]

Aquaculture using geothermal resources really has no economically competitive energy alternatives. If a farm wants to grow a certain species in a certain climate, only a geothermally heated farm can provide low-cost, dependable hot water that increases the fish's growing rate and can keep them alive during the winter. Heating with natural gas or propane is not cost competitive since it requires a costly burner and boiler as well as fuel. Solar energy is not a dependable source since it is not consistently available. Aquaculture for some species does exist without geothermal heating (as geothermal use is in the minority), but the locations are limited due to climate and the growth rates are reduced for a given species. Location is important because if the farm is close enough to its markets, the product can be shipped live at low cost.[24]

There are approximately 17 geothermal aquaculture operations in California.[2] Most are located around the Salton Sea in the Imperial Valley. Water temperatures influence aquaculture operations because each species has its own optimum temperature for growth. Growth rate is reduced when the temperature is above or below the optimum point. Mortality of the fish can occur at extreme temperature conditions. For example, tilapia grow best at 82°F (28^{o}C) to 86°F (30^{o}C) and can die when the water is below 50°F (10^{o}C).[23] Because of the hot desert climate often found in the Imperial Valley, high water temperatures are a concern for growers in the warm periods of the year. Many use ponds to cool the water before it is pumped to the fish ponds.

In total, these farms produce around 10 million pounds of fish per year.[3] Aquaculture has been the fastest growing application for geothermal direct-uses for the past 10 years.[6] From 1997 to 1998, the number of operations in the U.S. grew from 50 to 64. Tilapia farms have been the fast growing aquaculture application. This reflects the national trend in the growth of aquaculture. From 1991 to 1999, national production of tilapia quadrupled.[3]

In California, where 40 percent of the U.S. tilapia are produced, the high growth rate seems to be leveling off.Most tilapia production serves the live market (sold live at retail). The demand in the live fish market has reached equilibrium with prices declining.[6] Another species of fish grown in aquaculture, catfish, has also seen some difficult times because of competition from similar fish imported from Asia. Several high-profile failures of aquaculture businesses in the past few years have made the capital market very wary of geothermal technology. Tropical fish production, though comprising only 8 percent of the aquaculture business continues to thrive.[6]

Niche operators are likely to dominate any expansion of geothermal aquaculture for the near-term. In order for there to be substantial growth in geothermal aquaculture, there has to be an expansion in aquaculture of new species, since growth in the farming of existing species seems to have leveled out in their market demand. Successful aquaculture businesses are usually started by people having a background in fish culture. Thus, project development typically comes from inside the aquaculture industry.

Spas and Pools

Possibly the oldest recorded use of geothermal water was for bathing and health. The history of balneology, using natural mineral waters for the treatment and cure of disease, is thousands of years old. Mineral waters have been used for bathing since the Bronze Age 5000 years ago, according to archeological finds.[25] The word spa derives from a natural hot spring of iron-bearing water in Belgium that was used starting in 1326 to cure ailments. The resort spring, called Espa (fountain, in the Walloon language), became so popular that in English, the word spa became the common term for any similar health resort. In the U.S. as well, natural hot springs have been used throughout its history; first by the early Native Americans as a sacred place, later by early Europeans settlers emulating the spas of Europe, and today as a place of relaxation and fitness.[26]

The use of mineral and geothermal waters in the U.S. is developed in three major types: the plush hot springs resorts with hotel-services and accommodations, the commercial plunges or pools and soaking tubs with camping facilities and a food service, and the primitive undeveloped springs without any services.[26] Typically, existing resorts and hot springs have met health department requirements for chemical treatment by allowing the water to continuously flow through without treatment.

Today, there are approximately 60 sites using geothermally heated water in spas and pools in California (see the Geothermal Resources section). A typical resort application can be seen in Calistoga. In the mid 1980s, Calistoga became a “boomtown” with six major spas and resorts. All of these applications rely on shallow wells (approximately 200 feet deep) with temperatures from 170°F (77°C) to 200°F (93°C). This water is too hot to be used for bathing. It is cooled to 80°F (27°C) to 104°F (40°C) before it flows through the pools and baths. The water is then disposed of in drainage systems or using surface disposal without any treatment. Living quarters surround the various bathing areas and soaking pools and the landscaping features native plants and materials. Food and drink, small shops, and a fitness room are also available adjacent to the living quarters. An enclosed pool area provides privacy and also easy access to and from the living area. Often, a wading pool, warm lap pool, very warm pool and covered hot pool are provided. Another typical design for spas and resorts emphasizes public, semi-private, and private bathing and soaking facilities and does not include living quarters. The private and semi-private pools or baths can be used by a single family or group on an hourly basis.

Geothermally heated spas don’t really have an alternative energy source. One of the major attractions at a spa is that the water is naturally heated. A spa must be located near the spring or well. The hot water from the earth, containing certain minerals can give the spa meaning from a religious, symbolic, aesthetic, philosophical, or medical context.[25]

The typical temperature for a swimming pool is 81°F (27°C). Thus, in a geothermally heated pool, the hot water must often be cooled by mixing with cooler water, aeration, or in a holding pond. If the geothermal water is used directly in the pool, then a flow-through process is needed to replace the “used” water regularly. In many cases, geothermal water is used to heat water treated with chlorine which is in a closed loop. A heat exchanger is used to transfer heat from the geothermal fluids to the treated water. Geothermally heated swimming pools do have alternative energy sources if the geothermal water is not used directly in the pool. Solar energy or natural gas pool heaters are an alternative to geothermal heaters if the geothermal water does not flow directly into the pool. Comparing the alternatives, the price of natural gas could offset the higher prices for the heat exchanger and piping needed for the geothermal system. A solar heated pool is often less expensive in capital costs and operating costs than a geothermal system. However, a solar system cannot operate during all times (cloudy or at night) when it may need to operate. A geothermal system is available on demand throughout the year.

Growth of resorts and pool applications was essentially zero from 1995 to 2000 in the U.S. and in California.[6] This slowing of growth was caused by more stringent health and environmental regulations. Many practices used in existing resorts and hot spring pools such as "flow through" pools and surface disposal of effluent are no longer permitted. Geothermal water must be treated before disposal. Growth in the use of geothermal heating for resorts, pools, and spas is not forecast for the future in California.[6]

Space and District Heating

(excludes heat pumps)

Geothermal energy for space heating of residential, commercial and institutional buildings has a strong potential in California.[7] Currently, these types of applications operate at more than 25 sites in California (exclusive of the district heating applications described below). Typically, one or more production wells supply heated water (the warmer the better, with temperatures of 160°F (71°C) to 180°F (82°C) being ideal, although systems with temperatures as low as 60°F (15.5°C) are being economically utilized). Often, the hot water is piped to a heat exchanger or through a heat pump where the heat from the geothermal fluid is transferred to a space heating system. If the geothermal water is clean enough, it can flow through the space heating system without a heat exchanger, but there is concern with corrosion and degradation of geothermal system components. Hot geothermal fluids can also flow through a separate heat exchanger to heat domestic hot water. If chemistry is relatively benign, the cooled and clean geothermal fluids can be discharged into a drainage system, or evaporation pond.

District heating systems provide hot water from a central location through a network of piping to individual homes or buildings. The heat is used for space heating and cooling, domestic water heating, and industrial process heat. A geothermal well field is drilled to provide the primary source of hot water for the system. Currently there are 5 district heating applications in California.[2]

There are two types of geothermal district heating distribution methods: open and closed. The open distribution system pipes the geothermal fluid directly to the customer from the well. Closed systems deliver the fluid to a central location where it goes through a heat exchanger that transfers its heat to another fluid. This heated system fluid is then delivered to each customer in a closed loop network. Central plants are included in approximately 40 percent of the geothermal district heating systems.[27]

In an open system, (similar to the space heating system described above) the geothermal hot water is stored in an insulated storage tank after it is pumped from a well. Hot water piped from the storage tank is used to heat air and water through heat exchangers at each building unit. The hot water is used for domestic hot water or industrial process heat. The heated air is used for space heating of homes and buildings or process heat.[1]

Disposal of the geothermal fluid may be a major issue for district heating systems compared to conventionally fueled systems. Geothermal systems produce a large amount of groundwater which must be disposed of after its heat is extracted. There are two general methods: surface disposal and injection. In surface disposal, the water is discharged directly to the earth's surface such as in a lake, river, or pond. It is considerably less expensive than injection, but can have problems if a large number of users share the same resource. The geothermal resource can decline in output from a reduced level of geothermal fluid below ground. Also, surface disposal can be limited by environmental regulations depending on how "clean" the geothermal water is. In some geological environments, geothermal fluid can contain higher levels of some regulated chemicals (such as hydrogen sulphide, boron, fluoride, and even some radioactive species) compared to surface water.[28] Analysis of the water before project development is thus prudent.

Injection is now practiced by about 30 percent of system operators, in reaction to aquifer declines, regulatory pressure or both. The development of a well to inject the geothermal fluid back into the aquifer can be challenging and expensive because of environmental regulations and more expensive drilling techniques that must be used.[28]

An example of an open district heating system is located in the City of San Bernardino. This geothermal system provides heating for 21 buildings including City Hall and the Radisson Hotel. Most of the customers of the system are large users, though some smaller buildings are connected. Geothermal fluids are produced from two wells each about 1000 feet deep. The geothermal fluid is about 128°F. The system uses an average of 150 gallons per minute, which is adjusted as needed. Eighteen miles of pipe, most of which is iron pipe with a foam and PVC insulating jacket, bring the geothermal fluid to each building. Heat exchangers in each building transfer the heat from the geothermal fluid to water used in a conventional heating system.[29]

For small- to moderate-size buildings, the economic benefit of direct-use geothermal, compared to alternative energy sources, such as natural gas and propane, will be sensitive to the depth to which one must drill in order to reach the required geothermal energy. Shallow borehole depths (tens to a few hundred feet) will usually be quite cost competitive with alternative energy sources, even when initial capital investment in equipment is considered [85, 86]. Deeper boreholes, approaching a thousand feet, can make the use of geothermal energy not cost competitive with natural gas or other energy sources. However, each site possesses unique attributes, and no absolute rule-of-thumb applies to all applications. Thorough analysis of all costs, including those associated with operations and maintenance, the effects of intermittencies, and stipulation of an acceptable payback period must be factored in to obtain a useful economic evaluation. Models of generic systems have suggested that, if a 1,000 foot deep borehole is required to obtain adequate geothermal fluids, and a payback period of 5 years is stipulated, a new geothermal heating system project will require a building of at least 100,000 square feet (assuming average heating energy requirements) in order to be cost competitive. For existing buildings where the cost of retrofitting an existing heat system is included, the building size requirement goes up to 225,000 square feet.[6]. As the required borehole depth drops to a few hundred feet or less, the overall building size required to achieve cost competitiveness drops rapidly.

The growth rate of geothermal space heating systems for buildings between 1995 and 2000 was constant at two percent per year. Most of these existing systems were developed with government subsidies and have been successful. Even so, municipally owned systems have difficulties in marketing their systems, which has resulted in several district heating systems having minimal use.[6] This situation reflects several factors, including the capital costs for retrofitting, the significant need for a motivational "hero" (discussed below), absence of general experience in the contracting and building communities, and inadequate resources for aggressive marketing. One economic study, The Economics of Connecting Small Buildings to Geothermal District Heating Systems, published by the Geo-Heat Center, shows that a customer penetration rate of 33 percent is necessary for a geothermal district heating system to be economically viable. However, to date, customer penetration rates have typically been around 10 percent. Most of the growth in this sector has been in additions to existing district heat systems rather than new projects. Without substantial increases in conventional fuel costs, this trend will likely continue.[6] The opportunities for new space heating and district heating projects are most significant for large, public sector building projects and new, dense cluster, owner-occupied construction in the public and private sectors. Significant improvements in the low growth rate of the space-heating sector are unlikely[6], in the absence of significant changes in market conditions.

Greenhouses

Geothermal greenhouse heating is one of the most popular geothermal direct-use applications. It is both economical and efficient compared to conventional fuel sources. Geothermal energy provides space heating in greenhouses, which extends the growing season and increases the rate of growth for plants in commercial markets. Heating is a major concern to greenhouse producers. This is primarily true due to the costs of purchase and operation of heating equipment as well as the potentially disastrous effects of a poorly designed system. Although solar energy represents a significant factor in greenhouse heating, supplemental systems are a necessity for year-round production. Greenhouse heating is an attractive application of geothermal resources because of the significant heating requirement of a greenhouse and their ability to use low-temperature geothermal fluids.

Non-geothermal greenhouses use fossil fuels, solar energy, or electricity to heat the greenhouse in several types of systems. Conventional fuel sources or electricity is used in forced air unit heaters, which have fans to circulate the hot air throughout the greenhouse. Solar heating uses a collector, heat storage facility, and a heat exchanger to heat the greenhouse air, though a backup heat source is required when solar energy is not available for extended periods. Finally, a central heat system can use a hot water boiler (using fossil fuels) to distribute hot water in a piped network to heat the greenhouse using forced air or radiant heating. This central-type of heating system is most predominant in large-scale multi-acre operations.

Geothermal greenhouses are very similar to the non-geothermal types just described above except geothermal fluids are used to heat the air or water normally heated by fuels, electricity, or solar energy. A borehole is typically drilled to provide geothermal fluid in the 90°F (32^{o}C) to 200°F (93^{o}C) temperature range. A heat exchanger is typically used to transfer the geothermal heat to a closed hot water system, which separates the geothermal fluid from the heating system to prevent corrosion and scaling in the heating system. Once this hot water is created, the system is very similar to the central-type heating systems of a non-geothermal greenhouse. Small greenhouse heating systems can use a standard forced air unit heater which uses the heated water to heat and distribute hot air to the greenhouse. Large operations can use radiant heating and finned tube and fanned coil units to heat the air and soil of the greenhouse. Under some climate conditions the geothermal system may use conventional energy sources for peaking. For example, if the amount of time that the heat load for the greenhouse is at its highest, say five days a year, and the rest of the year it only needs to be at 80 percent of that peak load, then it could be economically sound to design a geothermal system to meet the 80 percent of the peak load and utilize conventional fuels to provide additional heat during those short peak demand periods of time.[30]

Geothermal greenhouses offer the most stable direct-use application regarding growth and potential for expansion of existing and new applications.[6] Growth from 1995 to 2000 has been 9 percent annually in the U.S. These operations grow mainly roses, potted plants, and tree seedlings. Currently there are at least six geothermal greenhouse applications in California growing roses, cut flowers, potted plants, and vegetables. The growth in the geothermal greenhouse sector is predominately in large multi-acre operations, though the majority of the industry is made up of small individual businesses less than 2 acres. Most of the growth in greenhouse sector has been additions at existing locations rather than at new geothermal sites.[6] For most growers, heating costs represent only five to 10 percent of their total operating costs. Therefore, the choice of energy source is not usually the focus of making their decision to locate a business. The primary factors used in deciding on the location for a greenhouse focus on land and labor costs, market size and distance, and local regulations.[6] Often the grower's preference of heating system type is decided because of past experience and familiarity of growing a certain type of plant with that particular system. Economics and energy use may not be the primary drivers behind the choice of energy system to be implemented; the type of crop or potential disease factors may be the a major criteria in their decision-making.[30] The cut flower industry in the U.S. is seeing great competition from South American countries, which can produce flowers at low cost – even including the cost to transport their product to markets in the U.S.. [31]

Industrial Processes

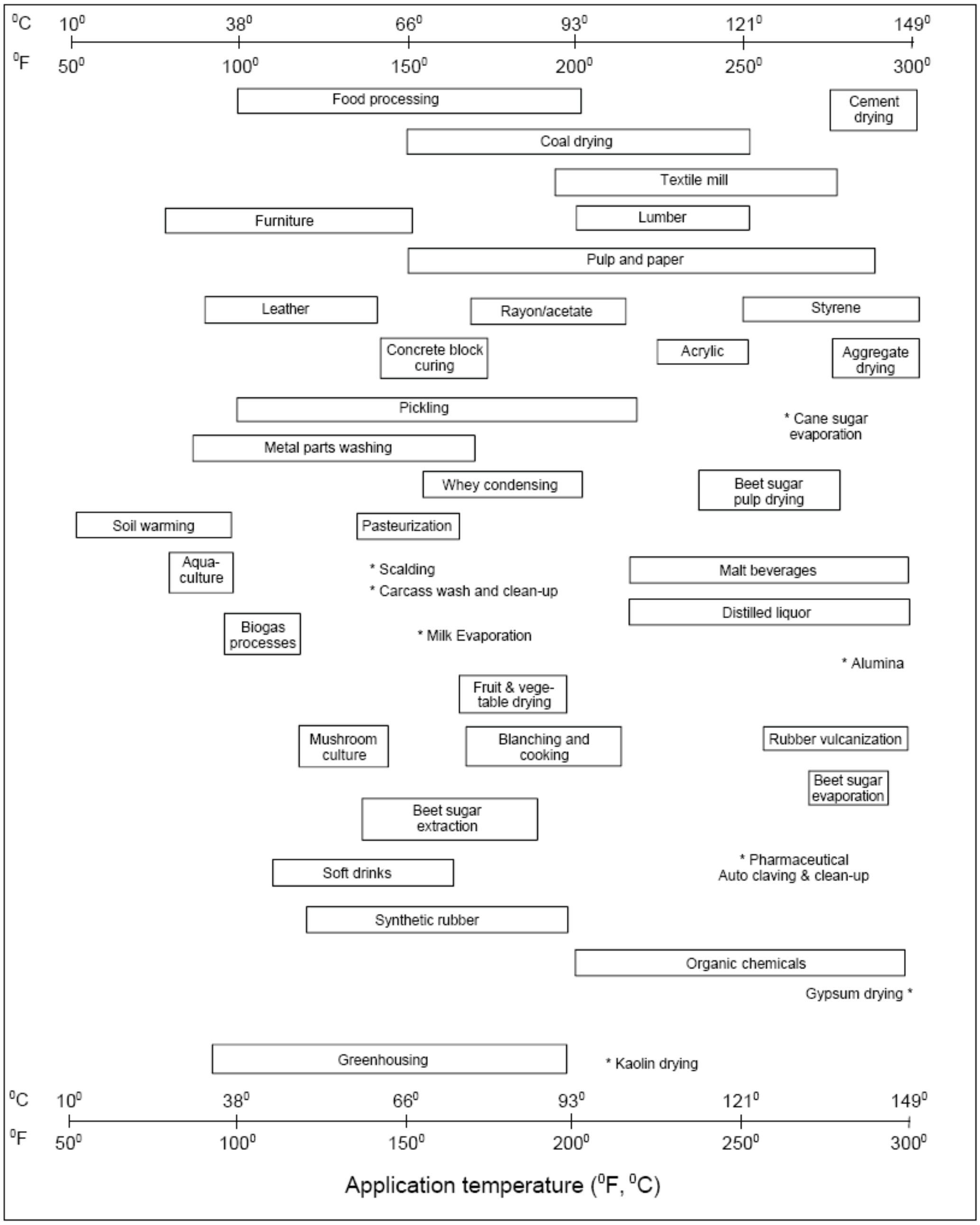
Because of the high load factor, industrial applications are a very enticing application of geothermal energy. Unfortunately its appeal has not translated into a large number of applications. In fact, in the U.S., industrial use of geothermal actually declined in the period from 1995 to 2000 due to the closure of a few large applications with no new growth to offset those closures.[6] Industrial applications make up the smallest portion of geothermal direct-use, with few applications in California. One explanation for this is that some industrial processes require steam at 250°F (121°C) or higher (Figure 2). [6] This temperature is outside the range usually considered direct-use, which typically utilizes low-to-moderate temperature geothermal fluids of 90°F (32.2°C) to 200°F (93.3°C). Geothermal fluid temperatures above 250°F (121°C) are usually exploited for electric power generation. Another reason for limited application of geothermal direct-use technologies in industrial processes is that, in many industries, lower-temperature process heat requirements are often satisfied by recovering (waste) heat from the process itself. Despite these situations, opportunities in the industrial sector remain that are attractive for geothermal heating from the energy use standpoint.

Currently in the U.S., geothermal direct-use applications for industry include enhanced oil recovery, zinc extraction, and food processing.[8]

One of the most successful industrial process heat applications using geothermal energy fluids is a vegetable dehydration plant in Nevada. It uses geothermal resources of 220°F (104°C) to dehydrate fruits and vegetables. There are many geothermal resources of this temperature range in California near agricultural production areas.

In California, CalEnergy Company operates a mineral recovery project in the Imperial Valley, producing 30,000 tons of zinc annually. Their operation harvests zinc from the high-temperature waste brine (182°F/83°C) from five of their existing geothermal electric power plants. After the metal is extracted using ion exchange technology, the remaining brine is injected back into the geothermal reservoir at about 116°F (47°C).

Figure 2 Temperatures of Industrial Processes and Agricultural Applications [8]



This combination of direct-use with electric power production is a positive strategy for development of direct-use applications, especially for industrial uses. One of the main attractions of this strategy is that relatively high-temperature fluid from the waste stream of a geothermal electric plant is produced without assuming the economic risks and costs related to the drilling of a conventional geothermal well.[6] Although barriers to this type of arrangement exist (e.g., land access, agreement of the resource and plant owner, location acceptance for the industrial user, fluid chemistry and increasing efficiency of new geothermal plants), it is a strategy that warrants further investigation.[31]

Prospects for Near-term Expansion

In this section we expand upon the general discussion presented above and explore, through a ranking scheme, the potential for new or expanded operations in California in the near-term. We used the literature search as well as interviews with geothermal energy experts to rank the generic technologies. Many of the questions we asked the experts during the interviews were centered on these issues. Criteria are:

- *Compare installed costs of technology to fossil fuels*

The geothermal application is compared to its non-geothermal alternative (if it has one). In some cases, such as for spas or aquaculture, there is not a non-geothermal alternative. In most cases, such as space heating, greenhouses and industrial processes (such as food drying), the geothermal applications require capital equipment (well drilling, heat exchangers, other well production equipment and disposal) different from that needed for conventional applications (such as boilers, burners, etc.). The cost differential will depend upon the specific application.

- *Operating costs of technology compared to fossil fuels*

In most cases such as space heating, greenhouses and industrial processes (such as food drying), the geothermal applications require additional operating costs for O&M of the well, heat exchanger, and other geothermal production and disposal equipment. However, the fuel costs for conventional alternatives (except solar energy) are relatively higher. The economic comparison between direct-use geothermal applications and conventional energy sources is predominantly decided by the tradeoff of low fuel costs and high capital costs for geothermal and high fuel costs and lower capital costs for conventional energy sources. Typically, front end capital costs are greater for geothermal systems; these are off-set by favorable life-cycle costs.

- *Development status*

Most geothermal direct-use systems can be considered fully-developed, with hardware commercially available. However, some industrial direct-use applications might be considered still developing and not commercially available.

- *The prevalence of applications of this technology installed in California and currently operating.*

According to the interviews, one of the major determinants for someone considering the direct-use of geothermal energy is their familiarity with the technology. Thus the potential for new applications in a particular sector increases if a large number already exist in the State.

- *Typical time for project implementation compared to competing technologies, given a proven resource and completed permits.*

The time necessary to complete a geothermal direct-use project is essentially the same compared to a non-geothermal project. The time to provide a proven geothermal resource and obtain regulatory permits is greater for many geothermal projects. In our comparisons we assume the geothermal resource is already developed and permits have been optained.

- *How large is the business for which the application is used in California?*

The impetus for expansion of a geothermal project is much greater for businesses that have a significant presence in the State. We based our judgment of that presence on the total revenues of that business in the State.

- *Does the geothermal resource requirements of the application (temperature, heat load, etc.). match the typical low-to-moderate temperature resource (temperature >122°F; well depth < 2,500ft; TDS < 5000ppm; well < 1mi from application site)?*

All of the identified significant generic applications have geothermal resources in California which match their resource requirements.

- *What are the labor needs of the application compared to fossil fuel technologies?*

The labor needs of the geothermal application compared to the competing conventional technology. Geothermal applications can, but not necessarily, need more expertise compared to conventional energy sources.

- *What are the transportation needs of the application compared to competing technologies?*

The transportation needs of the geothermal application compared to the competing conventional technology are typically the same.

- *Are there any obstacles/barriers to the development of the application in California? (Technical, institutional, economic, environmental etc.)*

Environmental regulations regarding the disposal of geothermal fluids (surface and other) are an obstacle to the expansion of geothermal uses in some regions. Health regulations regarding flow-through geothermal water in spas has been a barrier to new applications in California.

- *Is near-term economic outlook for this generic business in California good?*

The forecast of geothermal experts for the economic future geothermal applications is used to rank the applications.

- *How sensitive is this business to its energy needs?*

The sensitivity of the business to energy needs where the geothermal application is installed is used to judge the application.

- *Does the application require any special skills or expertise compared to competing technologies?*

If special skills are required for the geothermal application compared to the conventional system they are less competitive as such skills require different expertise that might not be locally available.

- *Any other overriding factors that could prevent development of application/project.*

Using our judgment, interviews with geothermal direct-use experts (Appendix 3), and an extensive literature search, a score for each criterion was given to each of the five generic applications.

A weighting was given for each of the criteria, based primarily on interview with experts[2]. The most important criteria have the highest weightings. The relative number of existing installations, the judgment of direct-use geothermal experts on the prospects for near-term expansion in California, and overriding factors that could prevent development of the project are the most heavily weighted criteria.

Table 3, page 31, displays the results of the application's assessment. Aquaculture was ranked as the generic application with the greatest potential, followed by greenhouses, space heating/district heating, spas, industrial applications ranked last. Aquaculture received a score of 92 with a higher score having the greater potential. Rankings followed as greenhouses (86), space heating/district heating (82), spas (81), and industrial applications (77). These ranks reflect, to a large extent, the existing applications found in the State and the application types which have seen the most growth in California in recent years.

Table 3 Assessments of Potential for Direct-use Applications

Number Rating 1 – 5 (5 is best)	*Weighting*	Aquaculture	Greenhouses	Space Heating / District Heating	Resorts, Hot Springs, Bathing, and Spas	Industrial
Compared installed costs of technology to competition.	*2*	3	3	2	4	3
Operating costs of technology compared to competition.	*1*	5	5	5	5	5
Development status	*1*	3	4	3	4	3
Number of applications of this technology installed and currently operating in the State.	*3*	3	2	4	5	1
Typical time for project implementation compared to competing technologies, given developed resource and permits.	*1*	4	4	2	5	3
How pervasive is the business for which the application is used in the state?	*2*	2	4	1	3	2
Does the geothermal resource requirements of the application (temp, heat load, etc) match the typical low-to-moderate temperature resources?	*2*	5	5	5	5	5
What are the labor needs of the application compared to competing technologies?	*1*	3	3	4	5	3
What are the transportation needs of the application compared to competing technologies?	*1*	4	4	5	4	4
Are there any obstacles/barriers to the development of the application in California?	*2*	4	4	3	1	4
Is near-term economic outlook for this generic business in California good?	*1*	4	2	4	1	4
How sensitive is the business to its energy needs?	*2*	4	4	2	2	3
Does the application require any special skills or expertise compared to competing technologies?	*1*	3	3	3	3	3
How has the state been judged by geothermal direct-use experts as to the prospects for near-term expansion?	*3*	4	2	3	2	2
Any other overriding factors that could prevent development of application/project.	*3*	3	3	3	1	3
Weighted Total		92	86	82	81	77

Geothermal Resources

This section discusses geothermal resources available in California. California has been divided into five major geothermal regions [34] (Figure 6) and those regions are ranked for their likelihood of fostering applications of geothermal direct-uses. Information included in this section includes data on the five geothermal regions, the criteria used for ranking, the actual ranking of those regions, and other pertinent information regarding direct-use resources in California.

The maps that follow show the prevalence of geothermal resources throughout California. The resources shown in Figure 3 are naturally occurring springs or developed wells. The Known Geothermal Resource Areas (KGRA), shown in Figure 4, are areas of the state designated by Bureau of Land Management as areas that are known to have high-temperature geothermal resources suitable for power production and direct-uses.

Figure 3 Geothermal Resources in California [5]

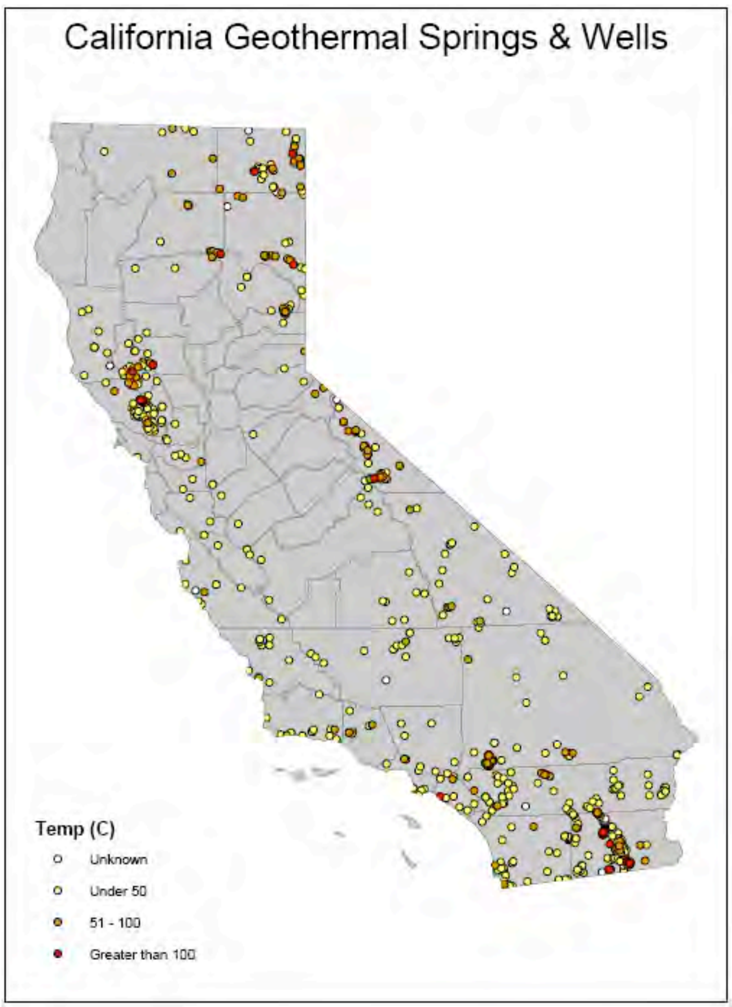
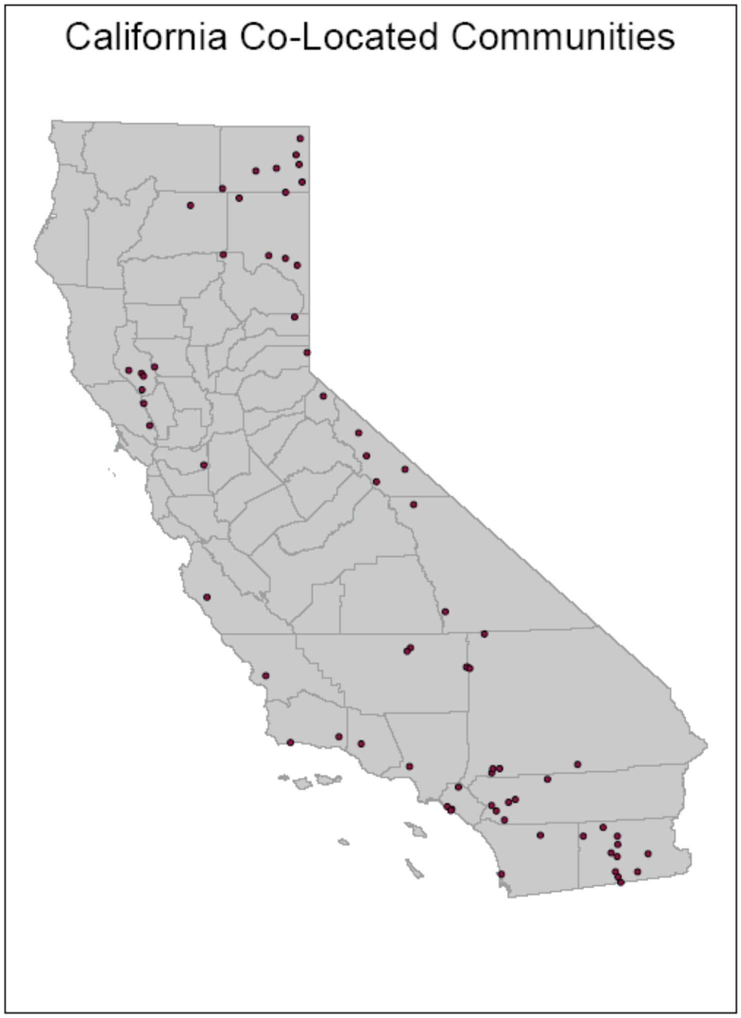


Figure 4 Known Geothermal Resource Areas [32]

Co-Located Communities

The Geo-Heat Center at the Oregon Institute of Technology developed a list of communities in California that are "co-located" with geothermal resources and are considered to have a higher potential to implement direct-use applications. A "co-located" community is one within five miles of a geothermal resource of 120°F (49^{o}C) or greater temperature. Such communities are important because they are population centers that have normal business infrastructure available to support an operation that may use geothermal energy or have the possibility to incorporate geothermal into current operations centered in that community. A map of the 71 co-located communities in California is shown in Figure 5 and a list of the communities is shown in Table 4.[33]

Figure 5 Co-Located Communities



Rating of Geothermal Regions

To accomplish the goal of this report, identifying geothermal direct-use projects in California with the highest potential for near-term development, criteria were selected to rank regions according to their likelihood of fostering such direct-use developments. A literature search and a series of interviews were completed. For the literature search, marketing and technical literature published in the past 20 years from organizations such as the Geo-Heat Center at the Oregon Institute of Technology, the Geothermal Resources Council, the U.S. Census Bureau and the California Energy Commission, as well as other state and federal agencies, were reviewed. The completed interviews included consultations with commercial and academic experts in the industry as well as geothermal direct application users and project managers. Also, updated data on California geothermal resources and generic applications was collected.

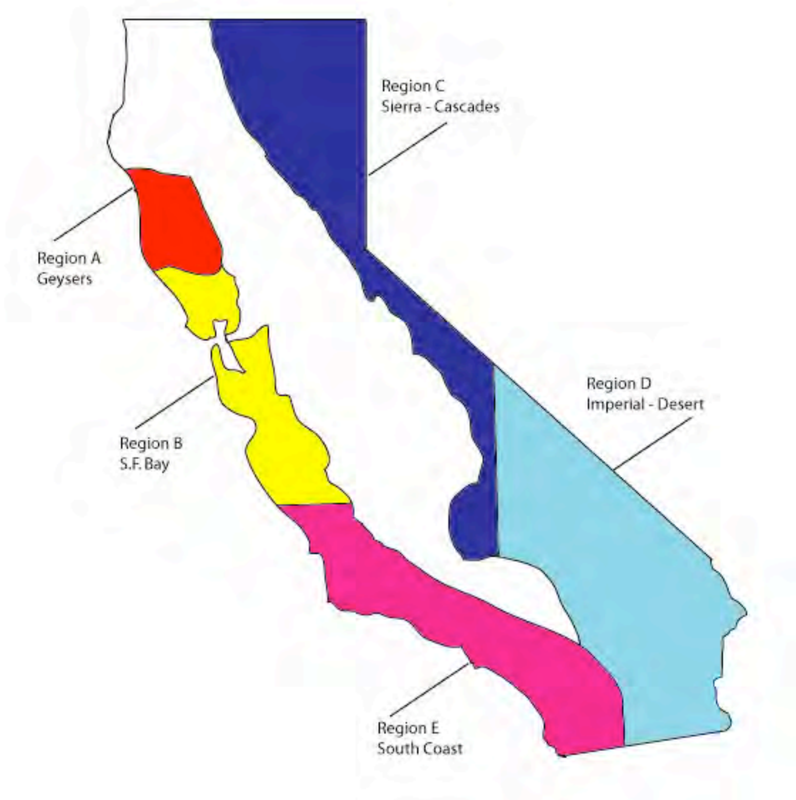
Table 4 Co-Located Communities [33]

Alturas	El Centro	Middleton/Cobb
Benton	Fort Bidwell	Mineral Hot Springs
Bieber	Gaviota	Montecito
Big Bend	Glamis	Newport Beach
Bishop	Heber	Niland
Bombay Beach	Hemet	Ojai/Meiners Oaks
Boyes Hot Springs/Sonoma	Highlands	Randsburg
Brawley	Holtville	Red Mountain
Bridgeport	Huntington Beach	Salton City
Byron	Johannesburg	San Bernardino
Calexico	Kelseyville	San Diego
Calipatria	Kings Beach	San Luis Obispo
Calistoga	Lake City	Susanville
Canby	Lake Elsinore	Tassajara Hot Springs
Cedarville	Lake Isabella	Temecula
Clear Lake	Lee Vining	Trona
Colton	Likely	Twentynine Palms
Coso Junction	Litchfield	Warner Springs
Costa Mesa	Los Angeles/Encino	Wendel
Day	Lower Lake	Westmorland
Desert Hot Springs	Loyalton	Widomar
Drakesbad	Mammoth Lakes	Wilbur Springs
Eagleville	Markleeville	Winchester
		Yorba Linda

Geothermal Regions

The five geothermal resource regions described in the 1982 Opportunities for California Commerce report [34] are shown in Figure 6. The regions are defined on the basis of known geothermal resources and natural geographic characteristics of the regions. The 1982 report, in part, addressed the same issues considered in this section, but used somewhat different and dated criteria. Part of the purpose of this section is to update that earlier evaluation.

Figure 6 Geothermal Regions of California [34]



Criteria for Ranking Geothermal Regions

The criteria used for ranking were based in part on the California Energy Commission reports Geothermal Energy: Opportunities for California Commerce: Contractor Report Phase I [34] and Final Report [87]. In those reports, specific geothermal sites were ranked to determine those with the highest likelihood of geothermal direct-use development. The ranking was completed by using resource temperatures, source depths, TDS (the total dissolved solids), potential heat load, financing, permitting, utility rates, land costs, raw materials, transportation, available labor base, business climate, community services, and living conditions factors. [34, 87]

Since this section of this report is only ranking large geographic segments of California, site-specific criteria such as resource temperature, source depth, TDS, heat load, financing and permitting factors are not appropriate. These factors will be reviewed in more detail when considering specific sites later in the report. The remaining factors were used and grouped together as: utility costs, land costs, manufacturing and transportation infrastructure, available labor base, state of the economy (in place of business climate), and quality of life (which includes community services and living conditions). Two more important factors were added to this ranking; the amount of current geothermal direct-uses in the region and the number of known geothermal resources. These and the other criteria are discussed below.

Current Geothermal Direct-use

The number of current geothermal direct-use applications is shown by region in the following section. The Sierra-Cascades, Imperial Desert and South Coast regions have much more current direct-uses than the Geysers and San Francisco bay area regions. The Geysers and San Francisco bay area regions do have a high number of spas & pools implementing direct-uses, but new regulations have been implemented in California that negatively affect the outlook for the growth of geothermal uses in these industries. (See Geothermal Direct-use Applications section). If spas & pools are ignored, these two regions have almost no currently developed geothermal direct-uses to support expansion of the lower-temperature geothermal applications..

Number of Geothermal Resources

This is the number of known wells and springs in the region. The region that stood out in this category was the Geysers region, which had fewer resources than the other four regions.

Utility Costs & Availability

The current electricity costs and availability of natural gas in each region were compared to see if any region(s) stood out with higher utility costs or lacked in natural gas resources, which would make geothermal direct-uses more cost competitive as an energy source. The electricity rates for small commercial customers were relatively consistent among the different regions, however, the availability of natural gas infrastructure in the Geysers, Sierra-Cascades and Imperial-Desert regions was much less than in the other two regions, which can be seen in Figure 12 in Appendix 1. The reduced level of natural gas infrastructure in these regions makes them more likely to foster direct-use developments.

Utility cost factors are also very site specific since each individual site will have local variation. These site-specific factors will be considered later in the report when rating specific sites.

Land Costs

To compare land costs among regions, the current median prices for homes were compared. The San Francisco bay area region was very expensive with a median price for a home being well over $600,000. The Sierra-Cascades, Imperial Desert, and Geysers regions were less than a third that of the San Francisco bay area.

Current Manufacturing and Transportation Infrastructures

To compare the available infrastructure to provide materials and transportation for businesses utilizing geothermal direct-use resources, the number of manufacturing jobs per area as well as the mileage of roads per area was compared. The San

Francisco Bay Area and South Coast regions had much more manufacturing and transportation infrastructure available than the other regions.

Available Labor Base
To compare the available labor base, the population densities of each region were compared. The population densities in the San Francisco bay area and South Coast regions were much higher than the other regions with several thousand persons per square mile. The Geysers region was much lower at only 54 persons per square mile.[35]

State of the Economy
The state of the economy in the individual regions is important to facilitate growth of new businesses that would foster a geothermal direct-use project as an energy source for their business. To judge the current state of the economy in each region, unemployment rates were compared. The South Coast region has the lowest unemployment rates at 4.6 percent and the Imperial Desert region has the highest at 9.9 percent.[36]

Quality of Life
The quality of life in each region was considered critical for bringing businesses and employees into the region. The EASI® Quality of Life Index was used, which is a measure developed from 29 different life-quality variables. The index takes into account such factors as weather, crime, and availability of services. Easy Analytic Software, Inc (EASI®) is a company that analyzes U.S. Census Bureau data to provide demographic solutions to customers. For the Quality of Life Index, weights are assigned based upon each variables importance to a high quality of life. A higher value index is considered a higher quality of life.[37] With the United States average being 100, and each of the five regions averaging over 140, all regions were considered to have a high quality of life.

Other Considerations
These region rankings do not include all factors that can affect geothermal direct-uses development. Several significant factors are site specific and cannot be quantified when evaluating large geographic regions. For example, the specific location of a geothermal spring or well, its accessibility, and proximity to an appropriate heat load (see co-located communities in Table 4) will certainly impact whether any direct-use project can be easily implemented.

Another important factor that was not considered in this regional ranking was the matching of appropriate applications to specific sites. The location, temperature, TDS, and other factors will affect whether a site is appropriate for a given application. Also, certain regions will be more likely to implement certain applications. For example, the colder mountain areas of the Sierra-Cascades region are more likely to implement district heating and snow melting systems than areas that are warmer in climate. There are also many more aquaculture direct-use applications in the Imperial-Desert region than in other regions, which could be due to many factors; prior aquaculture in the area, significantly lower land costs, different water disposal requirements than in an urban area, to name a few. Matching the applications to site factors will be considered when evaluating sites and areas within the selected regions. Regulatory issues may affect projects at a specific site. Water rights issues and other regulatory issues will have to be addressed on a project-by-project basis.

Geothermal Region Rankings

According to interviews with industry experts [38] and the Geothermal Energy: Opportunities for California Commerce report, one factor that has historically proven to be of great importance in affecting the potential success of a geothermal direct-use project has been the existence of a "hero". In most cases, the "hero" consistently and persistently advocated for the project, had experience dealing with direct-use development and was personally invested in the project. Such a "hero" would carry the project through the planning stage and through the many hurdles prevalent to direct-uses.[34] [38] [39] To account for this factor, past geothermal use was assumed to be the best indicator on a regional level of the likelihood of a hero being available: the more past geothermal use, the more likely it is that there will be "heroes" with experience in successfully dealing with the many nuances of geothermal direct-use development.

Due to the importance of this historical experience, current geothermal direct-uses are weighted the heaviest in the rankings, with a weight of three. Available geothermal resources and utility costs are considered the next most important factors, each with a weight of two. The number of geothermal resources is considered important for obvious reasons. The more resources that are available, the more sites that can be considered for direct-use. Utility costs are important because the higher the cost for, or lack of availability of, conventional energy sources that compete with direct-uses, the more attractive direct-uses become. Land costs, manufacturing and transportation infrastructure, state of the economy, and quality of life are all weighted as a one since they are assumed to affect the potential for direct-use developments, but not as significantly as factors weighted more heavily.

The rankings were done in each category by "1", "0" and "-1". A "1" meant that it was assumed that the factor would positively affect the regions opportunity for near-term geothermal direct-use development. A "-1" meant that it would have a negative effect and a "0" meant that it would either have no effect or an indeterminate effect on direct-use developments. Weightings were included for categories believed to have a more significant effect on geothermal development.

Table 5 Rankings of Geothermal Regions in California

	Weighting	Region C Sierra-Cascades	Region D Imperial-Desert	Region E South Coast	Region A Geysers	Region B S.F. Bay Area
Current direct-use	3	1	1	1	-1	-1
Number of Geothermal Resources	2	1	1	1	0	1
Utility Costs & Availability	2	1	1	-1	1	-1
Land Costs	1	0	0	-1	1	1
Manufacturing and Transportation Infrastructure	1	-1	-1	1	-1	1
Available Labor Base	1	0	0	1	-1	1
State of Economy	1	0	-1	1	0	0
Quality of Life	1	1	1	1	1	1
Overall Score		7	6	6	-1	-1

Three regions – the Sierra-Cascades, Imperial Desert and South Coast, were selected from the original five for additional review. This selection was done according to the ranking process described above and shown in Table 5. The complied data used for this comparison is shown in Appendix 1.

After reviewing potential projects in the selected regions, some consideration was given to how much some of the criteria used in the ratings really did affect the potential for geothermal direct-use developments. It could be considered that for some applications, a more rural labor base would be beneficial, rather than the urban labor base used to determine the ratings in the above table due to agricultural or other expertise not found in urban areas. The unemployment numbers used for state of the economy may actually have an opposite effect on potential geothermal developments. For example, a community with high unemployment may be more open to new geothermal projects due to the potential for new jobs.

Description of Geothermal Regions

The following descriptions include the five different regions and their geothermal characteristics. The general boundaries that define the regions, the numbers and types of current geothermal direct-use projects and the characteristics of the known geothermal resources in the region are included. High-temperature resource information pertaining to power generation is not included.

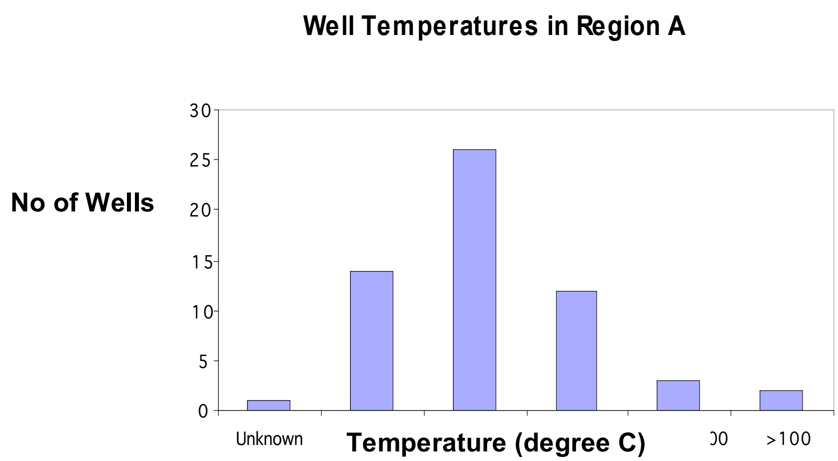
Region A – Geysers

Geographic Location
This region consists of geothermal resources located in the vicinity of Mendocino and Lake Counties.

Current Geothermal Direct-uses in Region A [2]

District Heating	0	Space Heating	1
Greenhouses	1	Industrial	0
Spas & Pools	5	Aquaculture	0

Geothermal Resources [5]
There are approximately 60 geothermal wells or springs in the region. The temperatures of these resources are shown in the chart below. The entire list of resources in this region, which this chart summarizes, is shown in Appendix 2.



Region B – San Francisco Bay Area

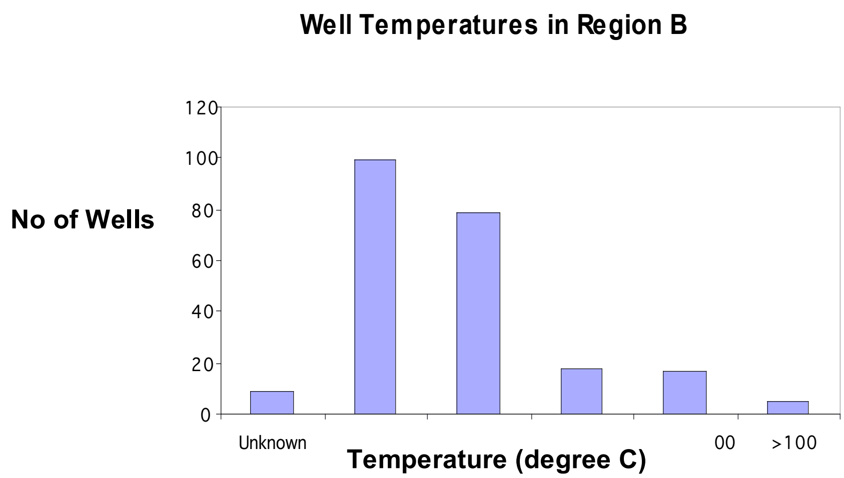
Geographic Location
This region consists of Sonoma and Napa Counties in the north, and the area south of San Francisco Bay to the Monterey/San Luis Obispo County line, bordered by the Pacific Ocean on the west and coastal mountain crest to the east.

Current Geothermal Direct-uses in Region B [2]

District Heating	0	Space Heating	0
Greenhouses	0	Industrial	1
Spas & Pools	10	Aquaculture	0

Geothermal Resources [5]

There are approximately 230 geothermal wells or springs in the region. The temperatures of these resources are shown in the chart below. The entire list of resources in this region, which this chart summarizes, is shown in Appendix 2.



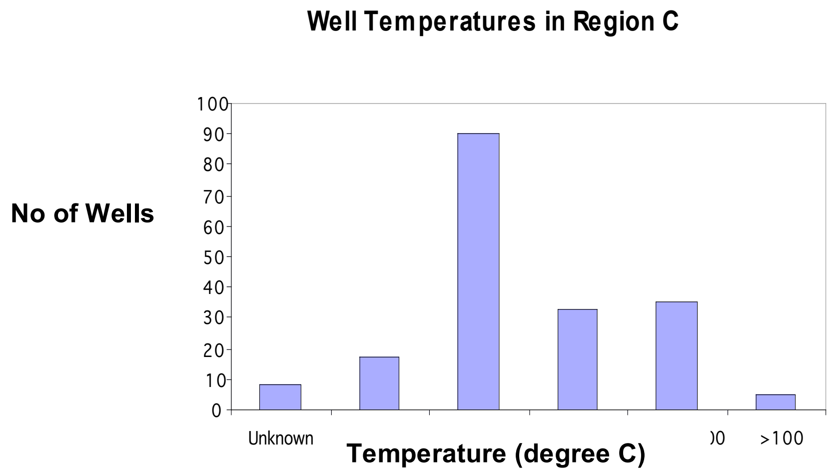
Region C – Sierra-Cascades

Geographic Location
This region consists of the Sierras and Cascades/Lassen areas as well as the eastern California deserts. This area is outlined on the west by the Sierra Crest and approximately Interstate 5 in Northern California and is bordered by Oregon to the north, Nevada to the east and the southern edge of the Sierras to the south.

Current Geothermal Direct-uses in Region C [2]

District Heating	2	Space Heating	9
Greenhouses	2	Industrial	0
Spas & Pools	14	Aquaculture	2

Geothermal Resources [5]
There are approximately 190 geothermal wells or springs in the region. The temperatures of these resources are shown in the chart below. The entire list of resources in this region, which this chart summarizes, is shown in Appendix 2.



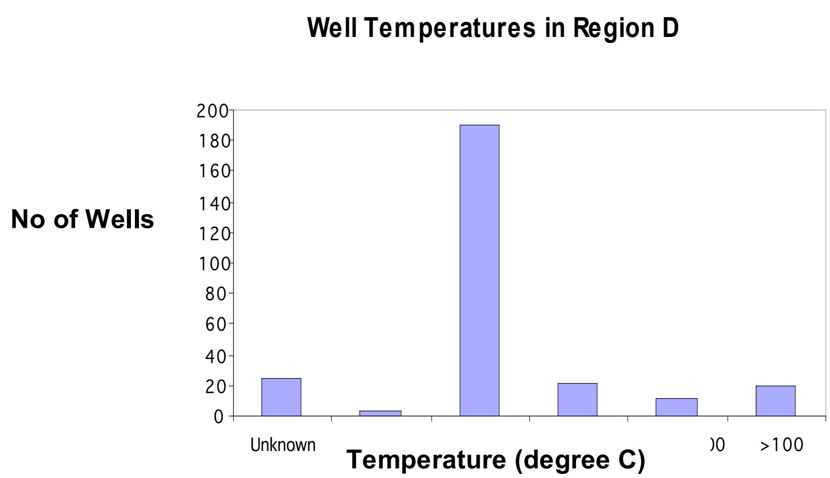
Region D – Imperial Desert

Geographic Location
This region consists of the area east of the south coast region to the Nevada/Arizona border and north up to Death Valley and bordered by Mexico to the south.

Current Geothermal Direct-uses in Region D [2]

District Heating	0	Space Heating	5
Greenhouses	1	Industrial	1
Spas & Pools	17	Aquaculture	13

Geothermal Resources [5]
There are approximately 270 geothermal wells or springs in the region. The temperatures of these resources are shown in the chart below. The entire list of resources in this region, which this chart summarizes, is shown in Appendix 2.



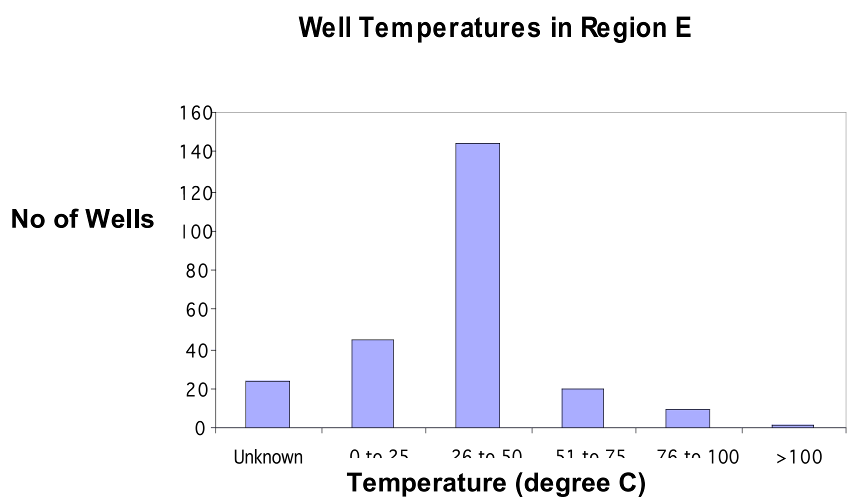
Region E – South Coast

Geographic Location
This region consists of the area south of the Monterey/San Luis Obispo Counties border to the Mexican border, and is bordered to the west by the Pacific Ocean and continues east to include the Pacific Crest, consisting of the Laguna, San Jacinto, San Bernardino, San Gabriel, and San Rafael Mountains.

Current Geothermal Direct-uses in Region E [2]

District Heating	3	Space Heating	9
Greenhouses	2	Industrial	0
Spas & Pools	14	Aquaculture	2

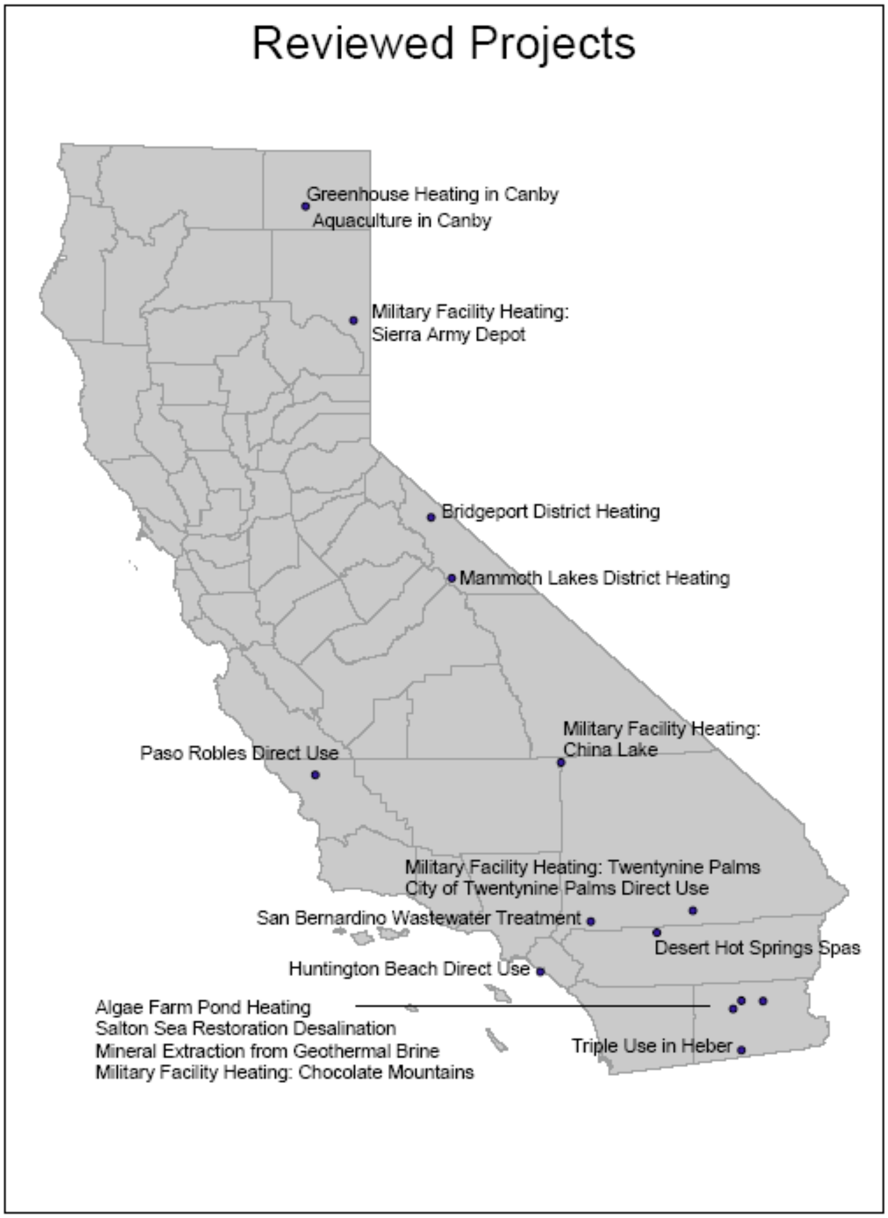
Geothermal Resources [5]
There are approximately 240 geothermal wells or springs in the region. The temperatures of these resources are shown in the chart below. The entire list of resources in this region, which this chart summarizes, is shown in Appendix 2.



Review of Potential Geothermal Projects

This section discusses projects identified through extensive literature searches and interviews. An overview of 17 potential projects is provided as well as detailed assessments, including engineering and/or economic assessments where possible, of 10 of those projects. Initial ratings of the 17 projects were completed that determined the projects with a higher likelihood for near-term development. Further information was pursued for those top-rated projects, and detailed assessments and final rankings were developed.

Figure 7 Potential Projects Reviewed in this Report



Potential Projects in Region C – Sierra Cascades

Mammoth Lakes District Heating Project

Using geothermal energy to provide space and domestic water heating in the community of Mammoth Lakes has been considered for more than twenty years. However, Mammoth Lakes is still without a geothermal district heating system. This report evaluates if Mammoth Lakes can overcome barriers and how this can be accomplished. Information from a recent economic assessment of the projects is included.

The community of Mammoth Lakes is located in the Mono – Long Valley Known Geothermal Resource Area (KGRA) and has significant geothermal activity and resources. Two miles east of the community is the Mammoth Pacific Limited Partnership (MPLP) Casa Diablo geothermal power plant, providing 40 MW of power to California. MPLP plans to expand the capacity of that plant and possibly build another geothermal power plant closer to Mammoth Lakes.[10]

A proposed district heating project would use waste heat (fluids) from the MPLP plant to provide heating to the community. Waste heat would be pumped from the power plant to Mammoth Lakes, and once used, would be returned to the plant to be used as cooling water and injected into the reservoir. The MPLP plant is currently air-cooled, which is not as efficient as a water cooled plant, especially in the summer months. A source of cooling water for the power plant would make a project mutually beneficial to both MPLP and the community of Mammoth Lakes.[40]

A district heating system for Mammoth Lakes, as originally proposed, would be developed in phases. The first phase would provide heating for public users, such as the waste water agency, community college, schools, hospital, town offices and forest service offices. There would be a few residential customers included in the first phase. The second phase would include a snow melting system primarily for sidewalks and parking lots. Recently built sidewalks in the community have pipes for heating laid in them and are ready for use in a snow melting project. The third phase would be a combined effort with the State of California Department of Transportation (CalTrans) to provide for snow melting on Highway 203 between Mammoth and Highway 395. This phase would be used as a pilot project for other possible snow melting projects with CalTrans. The final phase would connect other residential and commercial areas to the district heating system.[40]

Two recent reports have been written that investigate the potential of a geothermal district heating system in Mammoth Lakes. The most recent [10], looking at the first phase of developments, was completed by FVB Energy. This study found that the heat source being two miles away from the community created capital costs too high to be supported by the customer load included in the first phase. However, if a source closer to town could be developed, the economics of the project would improve. MPLP is actively pursuing other heat source wells closer to Mammoth Lakes. The company has development leases they want to make use of before the leases expire in the next few years.[40]

There is strong community support for a district heating system, though no formal commitments from developers or property owners exist. The interest in Mammoth Lakes is highest with public agencies and less with condominium owners. Most condominiums in the area have electric heating and have no installed forced air heating systems. Forced air heating systems have much lower capital costs compared to those associated with 1) electric heating and 2) converting electric heating to a district heating system. The cost to convert electric heat systems to district heating is much higher, possibly high enough to be prohibitive. Residential customers are interested in lowering monthly heating bills, but are concerned with initial capital costs. It should be considered whether a home owner would take on the initial capital conversion cost or whether the costs for conversion would be assumed by the developing agency and included in the district heating energy rates.[40]

The Mammoth Community Water District (MCWD) is the agency that would develop and operate a local district heating system. MCWD has been very interested in pursuing a district heating system, but they have been hoping for some government assistance. There is some discretionary property tax revenue committed to a geothermal district heating project and the project was online to be part of the U.S. Department of Energy's "Geo-Powering the West" initiative several years ago, but funding has since fallen through. Lack of funding has been an on-going problem with this project. District heating in Mammoth Lakes has been included in studies for 25 years, but has yet to happen, primarily due to its large size and comparatively large capital costs.[40]

Several other barriers to this project exist. Propane operators in the area are looking to block a municipal geothermal district heating project due to its possible impacts on existing and future possibility of installing a private propane distribution system. Such businesses are concerned that privately funded propane distribution systems could not compete with a government subsidized geothermal district heating system. There is no natural gas delivery system in the area; therefore the only existing alternatives are wood-burning stoves, tank storage propane, and electricity. Electricity is comparatively expensive for heating, and wood-burning stoves have begun to create air quality issues. Also, the lack of similarly sized systems in the United States makes a geothermal district heating system like the one proposed for Mammoth Lakes, risky in the eyes of users, lenders and developers.[40]

Benefits
In their analysis of a geothermal district heating system for Mammoth Lakes, FVB Energy suggested the following as benefits to end users of a system. A geothermal district heating system will[10]:

- Reduce fuel and electricity expenses
- Reduce operation, maintenance and repair costs for heating equipment
- Reduce exposure to future increases in energy prices
- Reduce exposure to disruptions in energy supply and increase reliability of heating system
- Provide better quality heating service – hot water heat provides a more comfortable and pleasant indoor environment
- Improve overall appeal and value of property with high quality heating service and the use of environmentally-friendly energy
- Eliminate the hassle and effects of wood-fueled heating, including procurement and use of fuel, operation, coping with “burn bans”, and reduced air quality
- Improve ease of property management by having a simple, reliable, high-quality heating source

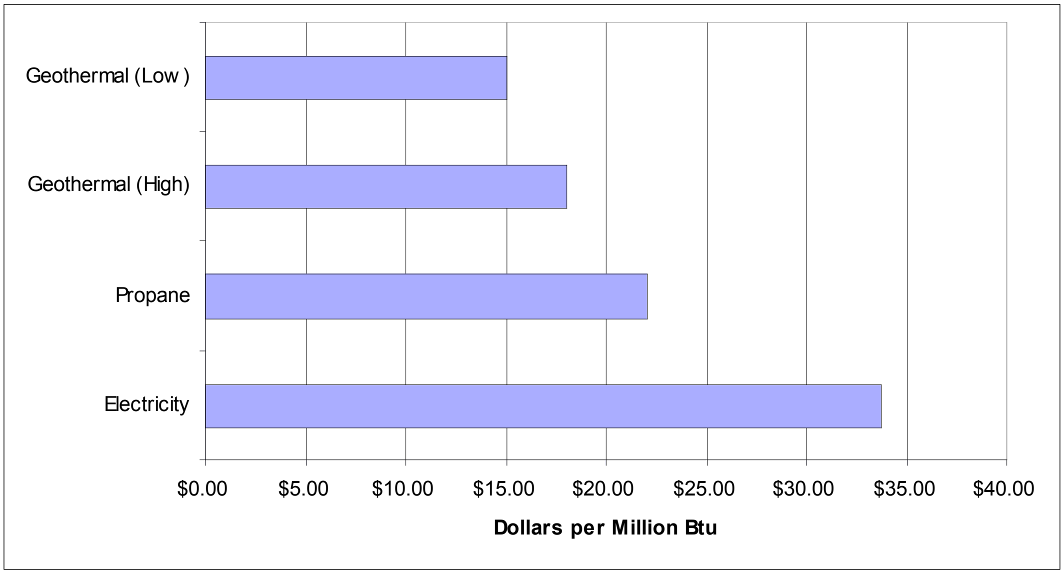
FVB Energy also suggested the following benefits for the community that would be derived from a geothermal district heating system[10]. Mammoth Lakes would

- Become the first community in the United States to have the majority of the power and heating provided by geothermal energy
- Be better insulated from energy price increases or disruptions
- Have reduced energy costs
- Be more desirable as a place to live, do business, develop in, or invest in real estate
- Provide diversity in energy resources as well as self-sufficiency for the community
- Create jobs through construction and expansion of the district heating system
- Keep money spent on energy in the community
- Reduce pollution from wood-fired heating systems

Costs

Energy costs for heating in Mammoth Lakes are relatively expensive. The two basic energy sources for heating in the area are electricity and propane. The average winter-time costs of heating for propane, electricity and geothermal are shown below in Figure 8. The high and low costs for geothermal are for different scenarios discussed below and the range allows for some uncertainties. The prices for geothermal are for the first year, with the real price declining thereafter to about $5 less (2004 dollars) in 15 years. Currently, the total annual space and water heating cost in Mammoth Lakes is approximately $10.8 million, $6.3 million for electricity and $4.5 million for propane.[10]

Figure 8 Heating Energy Costs – Delivered [10]



If energy costs economics were based solely on the costs described above, a geothermal district heating system for Mammoth Lakes would most likely already be in place. However, the primary economic barrier to a geothermal district heating system is the up-front, capital costs associated mainly with retrofitting,, which would include costs to develop and install infrastructure for district heating, for current customers to convert their existing heating systems to connect to a geothermal district heating system, and for potential customers to install systems compatible with district heating. For new buildings in which a hot water-type distribution system would be used for space heating, and for which accommodation has been made for connecting to a geothermal district heating system, capital costs for construction would be reduced. However, new or current buildings not using a hot water type system would have higher initial capital costs for connecting to a district heating system.[10]

In their report, FVB energy found that both new buildings and buildings currently using hydronic heating systems (hot water type distribution systems) would make good candidates for conversion to a district heating system. However, retrofitting buildings using electric heating was found to not be cost-effective. In addition, FVB Energy conducted a preliminary economic analysis of the geothermal snow-melting process to be used for sidewalks, parking lots and roads. Although the report found that geothermal snow-melting is expensive, there are considerations that are difficult to calculate in such analyses, such as convenience that snow-melting would provide for residents and visitors, safety, aesthetics improvements, and reduced maintenance.[10]

Load Scenarios [10]

Three load options were considered by FVB Energy in their analysis of a district heating system at Mammoth Lakes. The first, the Base Case Load Scenario option, would provide heating for about 38 percent of the total 128 MMBtu/hr (million Btu per hour) potential load in Mammoth Lakes. This base case focused primarily on future loads, with only 7 percent of the load consisting of existing buildings. As discussed above, new buildings are the best prospects for connecting to a district heating system.

The second option was the Reduced Load Scenario. This option focused on a much tighter geographic area. The customers are selected MCWD buildings including the college and cultural center complex, the hospital, the elementary and middle schools, and the new library. The total load in this option is approximately 12MMBtu/hr, or 9.5 percent of the total potential load. Existing buildings represent 27 percent of this option.

The third option, Reduced Load Scenario with Low-Income Housing (LIH), is identical to the Reduced Load option except it also includes a planned low-income housing development. This development is projected to be quite large and doubles the load of the prior scenario to 25 MMBtu/hr, or 20 percent of the total potential load. This option includes 13 percent existing buildings.

From these load options, several alternative designs were proposed and reviewed. They are:

Alternative 1 [10]
The geothermal resource is assumed to be waste heat water from the MPLP power plant and the load option used is the Base Case Load Scenario. This alternative includes three separate piping loops. Loop 1 runs from the power plant up to a set of heat exchangers located within a facility on MCWD property. This transmission line routes hot brine directly from the power plant to the MCWD and then into the power plant where it is used for cooling and injected back to the resource. A 150 psig (pounds per square inch by gauge) hot water boiler would be located on MCWD property for backup.

Distribution Loop 2 would be separated from loop 3 by heat exchangers. Loop 2 would be operated at a maximum pressure of 150 psig. Since commercial buildings are typically designed for a 150 psig pressure rating, customers on the district heating loop could be connected to the system directly (i.e.they will not have to be separated from the district system by a heat exchanger). The benefits of directly connected customers are two-fold. First, eliminating the heat exchanger reduces the cost of customer interconnections. Second, when customers are connected directly, the supply temperature that must be delivered from the power plant is reduced, thereby reducing the amount of produced fluids that must be used by the district system. Indirect customer interconnections are typically designed with a heat exchanger approach temperatures of 10°F, meaning the supply temperature from the plant would have to be at least 10°F higher to deliver the supply temperature requirement for indirectly connected customers.

Distribution loop 3 would run to the furthest projected customer on the distribution system. This loop would also be operated at 150 psig maximum pressure to allow direct customer connections. Since the projected customers for loop 3 do not include existing customers with commercial building designs, we have assumed that these customers can be delivered supply temperatures 5°F below those on loop 2.

Business analysis data for Alternative 1 is provided below in Table 6.

Alternative 2 [10]
The geothermal resource is assumed to be waste heat water from the MPLP power plant and the load used is the Base Case Load Scenario. This alternative consists of two separated piping loops. As, in Alternative 1, Loop 1 runs from the power plant up to a set of heat exchangers located at the MCWD facility.

Distribution Loop 2 runs from the MCWD to the furthest projected customer on the system. Due to the large elevation difference between the MCWD and the furthest located customers, much of this distribution loop must be designed with a 300 psig pressure rating. This dictates that most customers on the distribution system will have to be connected indirectly with heat exchangers, since most buildings are not designed to operate at that higher pressure. Also, a more expensive 300 psig backup boiler will be installed on the MCWD property.

A business analysis was not developed for Alternative 2 for several reasons. First, the higher expense of connecting nearly all customers with an indirect connection, especially since these customer interconnections will need to have 300 psi rated heat exchangers, are more than 50 percent more expensive than customers using 150 psig exchangers. Also, commercial customers are expected to require 190°F at peak demand. Connecting those customers indirectly rather than directly will require the initial resource temperature to be 10°F higher, which will result in greater use of power plant resources. Second, it is difficult to connect domestic hot water systems. The heat exchangers typically used for domestic hot water could not be used with the 300 psig district heating system pressure. This would mean that domestic hot water heating would have to be connected in series with the space heating heat exchangers, which would lower the temperature available for domestic hot water heating to a level not high enough to meet commercial customer hot water requirements.

Alternative 3 [10]
The geothermal resource is assumed to be waste heat water from the MPLP power plant and the load used is the Base Case Load Scenario. Like Alternative 2, this alternative consists of two separate piping loops. However, in this design, the heat exchangers are moved to the power plant property. Loop 1, the brine loop, is restricted to the power plant site. The treated water district heating loop 2 would run from the power plant to the furthest customer on the distribution system. This loop would operate at 400 psig and would require a more expensive 400 psig backup boiler. A positive aspect of this alternative is that hot brine does not leave the power

plant site. This eliminates any potential difficulties related to obtaining permits for brine transmission off the power plant site..

A business analysis was not developed for Alternative 3 for the same reasons one was not developed for Alternative 2.

Alternative 4 [10]
The Reduced Load Base Scenario is used and the geothermal resource supply is different than Alternatives 1, 2, & 3. The proposed resource would be located on MCWD property much closer to town, reducing the overall capital costs for the previous alternatives by over 10,000 trench feet of transmission piping eliminated. In addition to reducing the piping requirements for the project, this alternative is also free from production fluid-use limitations. A benefit is the ability to operate the distribution system at a much higher supply temperature than in the prior alternatives. Pipe sizes in the distribution system loop could be reduced. This would also eliminate the domestic hot water supply issues described in Alternative 2. However, higher temperature supply water requires higher operating pressure in the district heating system to prevent the water from boiling. Due to this higher operating pressure, all customers in the system would need to indirectly with heat exchangers, increasing the cost of connection to the district system.

This system would consist of a small piping loop between the geothermal well, heat exchangers and the re-injection well. The other distribution loop would operate at 230 psig maximum pressure and run from the MCWD site to the furthest projected customer.

Unfortunately, the prospect of developing a resource and re-injection well on MCWD property is uncertain. A resource must be proved and wells completed within the vicinity of the MCWD property before this alternative could be considered further.

Business analysis data for Alternative 4 is provided below in Table 6.

Alternative 5 [10]
This alternative is identical to the design for Alternative 4, except the future low-income housing development would be included on the district heating system. Business analysis data for Alternative 5 is provided below in Table 6.

Business Analysis
A summary of capital costs analysis for the first phase (for public users) of geothermal district heating infrastructure study completed by FVB Energy is shown in Table 6.

Table 6 Summary of Infrastructure Capital Costs [10]

Capital Item	Capital Cost (1000's)		
	Alternative 1	Alternative 4	Alternative 5
Distribution System	$14,185	$2,860	$3,865
MPLP Power Plant Pumping Station	$234	$0	$0
MCWD Pumping Station & Backup Boiler	$889	$414	$573
Intermediate Pumping Station	$273	$0	$0
Geothermal Wells	$0	$1,247	$1,247
Building Interconnections	$1,897	$649	$1,029
Totals	$17,479	$5,170	$6,716

Economic Analysis

The alternatives above were run through economic analysis by FVB Energy, and only Alternative 5 was found to be economically feasible, because of its high rate of return of 15 percent. Both Alternatives 1 and 4 produce much lower returns and, unlike Alternative 5, could probably not be financed. For their analysis, FVB Energy assumed that 30 percent of construction and development costs were funded with MCWD or partner equities. A conservative inflation rate of 2 percent was assumed, although higher inflation rates would yield better returns.[10]

Conclusions [10]:

- Geothermal district heating in Mammoth Lakes has the potential to be economically feasible and provide significant benefits to customers and the community.
- Significant initial capital investments must be made in advance of developing an expected customer base. The estimated investment for the smaller district heating system described in Alternative 5 would be $6.7 million in 2004 dollars
- The originally proposed application of using waste heat water from the MPLP Casa Diablo power plant is not feasible due to high capital costs.

Recommendations [10] MCWD should:

- Seek funding for test drilling to confirm the availability of a geothermal resource of at least 275°F near the community.
- Continue discussions with potential customers identified in Alternative 5 to remain up to date regarding plans for building developments and renovations.
- Consider options for financing a geothermal district heating project, including potential partnerships with the private sector to create equity for system financing.

Aquaculture in Canby

The In Search of Truth community (I'SOT) in Canby, CA has recently installed a geothermal district heating system with assistance from the California Energy Commission, the National Renewable Energy Laboratory (NREL), and the Federal Department of Energy (DOE). I'SOT is planning to expand uses of geothermal energy for their facilities. I'SOT is preparing for their next step of providing for all their electricity needs with a small geothermal power plant. Plans include drilling a new well, which is expected to provide 223°F waters at a flow of 500 gpm (gallons per minute). After the new plant is completed, I'SOT intends to use the waste heat fluid (expected to be about 145°F after electricity production) for greenhouse and aquaculture facilities. These facilities would be located within 1000' of the new well,.[41]

I'SOT has developed a partnership with Ron Kettler who currently raises Bass and Catfish at Kelly Hot Springs in a geothermal aquaculture facility. He also has a license to produce Tilapia, a popular fish for eating. Mr. Kettler would like to expand his current operation if heated water from an I'SOT geothermal power plant becomes available.[41]

To assess the potential for geothermal aquaculture in Canby, a generic aquaculture pond model was created for this report and an analysis method[23], developed by the Geo-Heat Center, was applied to determine the heating requirement for that model. From those calculations, the amount of geothermal water required for different pond configurations were determined.

Table 7 Ideal Growth Temperatures for Aquaculture [23]

Species	Ideal Temperatures for Growth
Catfish	82°F to 87°F
Tilapia	72°F to 86°F
Bass	61°F to 66°F

In Table 7 above, the ideal temperatures for Catfish, Tilapia and Bass are shown. A temperature ideal for both Catfish and Tilapia, of 82°F, was used. If Bass are raised, then the geothermal resource requirements will be less, due to the lower temperatures required. A generic model of a pond (10ft by 50ft and 5ft deep) was used for calculations. The peak losses shown in Table 8 are for a low air temperature of -15°F (determined from a 10-year low in Alturas, CA) [42] combined with a sustained wind speed of 10 mph.

The methods of heat loss in an aquaculture pond include evaporation, convection, radiation, and conduction. Evaporation accounts for the most significant loss of heat in an aquaculture system, amounting to approximately 1000 Btus for every pound of water that evaporates. Convective losses are caused by the cold air passing over the pond surface. Radiant losses involve transfer of heat to the surrounding air and water vapor near the pond. Conductive loss is associated with heat transfer to the walls of the pond.[23]

Table 8 Peak Heat Losses for 84°F Aquaculture Pond in Canby

Heat Loss Method	Heat Loss
Evaporation	132,000 Btu/hr
Convection	98,000 Btu/hr
Radiation	39,000 Btu/hr
Conduction	11,000 Btu/hr
Total	**280,000 Btu/hr**

As discussed by the Geo-Heat Center in the Aquaculture Information Package, picking the right heating capacity is a complex design challenge, which must incorporate environmental factors, specific pond characteristics and the species being raised. The calculations included in this report are very basic and do not account for such complex design issues.[23]

Aquaculture ponds must provide clean, oxygenated water for the live fish stock. This can be done through the use of flow-through ponds, which allows new water to flow in and old water out. Typically, for Catfish and Tilapia, 3 complete water changes per hour would be enough to provide fresh water and oxygen and remove wastes. If a flow through pond isn't used, aeration and filtration systems must be used to provide oxygenated and cleaned water.[23]

To provide 80 percent of the peak load from a geothermal heating system for the Canby system, 224,000 Btu/hr must be available. This heat load could be provided with a minimum of 7.3 gallons per minute of 145°F fluid if used in a re-circulation pond implementing aeration and filtration systems. However, in the case of a flow-through pond, much more geothermal water is required.

For a flow-through pond of the size described in the generic pond model, 56,000 gallons per hour would be required to provide three complete water changes per hour. To meet this, geothermal fluids would have to be mixed with fresh water. With flow-through ponds, meeting the peak heating load is not an issue. Since new water at the appropriate temperature is constantly being brought in to the pond, the water does not have time to significantly drop in temperature. If a fresh water source is assumed to be 60°F and the geothermal water is 145°F, a mixture of 28 percent geothermal water and 72 percent fresh water is required to provide a water temperature of 84°F. To meet the 56,000 gallons per hour requirement, 260 gpm of geothermal fluids would be required. However, if the fresh water temperature is colder than 60°F (which is very likely in winter), more geothermal fluids would be required. For fresh water at 40°F, 42 percent, or 392 gpm of geothermal fluids would be necessary. Table 9 below shows the quantities of geothermal fluid required for different scenarios.

Table 9 Geothermal Requirements for Aquaculture

Fish	Required Pond Temperature	Fresh Water Temperature	Geothermal Water Required	
			Percentage of Total Flow	Flow
Tilapia & Catfish	84°F	60°F	28%	260 gpm
		40°F	42%	392 gpm
		Re-Circulated	100%	7.3 gpm
Bass	63°F	60°F	3.5%	40 gpm
		40°F	22%	204 gpm
		Re-Circulated	100%	3.2 gpm

In conclusion, aquaculture in Canby is feasible with the assumption of an available resource (effluent from the planned geothermal electric plant) of 145°F at 500 gpm. Some consideration will have to be given to what type of pond will be implemented. If a flow-through pond is used, only one or two Tilapia/Catfish ponds can be supported. The number of supported ponds is higher for Bass, however in the winter, much more geothermal fluid is necessary, which will reduce the number of supported ponds to two or three. If flow-through ponds are used, it must be determined if there is an available fresh water resource. If re-circulation is implemented, many more ponds could be supported with the resource, however, there is additional expense associated with the aeration and filtration equipment that must be used with re-circulation. Waste water from an aquaculture operation in Canby could be used for irrigation in the agricultural fields that surround this area. And, due to the lower temperatures needed, an aquaculture facility in Canby could make use of low-temperature geothermal fluids after they have been used in either the current district heating system or proposed greenhouse heating system in lieu of the effluent from a geothermal electric generation plant.

Greenhouse Heating in Canby

As described in the Aquaculture in Canby Section above, I'SOT would like to partner with a greenhouse operator in the region and provide heating for new greenhouses from waste heat water from their geothermal power plant.[41]

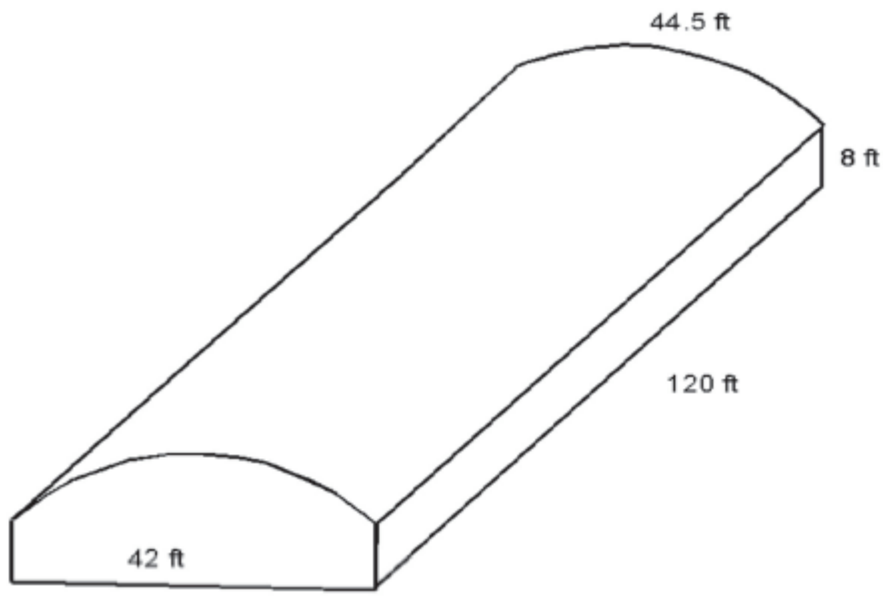
To assess the potential for geothermal greenhouse heating in Canby, a basic greenhouse model was created and economic analysis developed by the Geo-Heat Center was applied.

To aid in heat load calculations, average annual Heating Degree-Days were calculated to be 6738°F and a 10-year low was -15°F (for a weather station in Alturas). [42] The temperature difference used for peak load calculations was 60°F.

(For more information on calculating peak loads, annual loads and load factors, see the Military Facility Heating section.)

A generic greenhouse used for these calculations can be seen in Figure 9. The generic greenhouse is made up of fiberglass siding and a double-poly roof. The double-poly roof has two layers of plastic film separated by air space. The air space is maintained by a small blower that pressurizes the volume between the layers. Based on modeling provided by the Geo-Heat Center, a peak load of 496,400 Btu/hr was calculated.[43] The annual load for this greenhouse is 1,338 MMBtu and the load factor, which is the peak load vs. the annual load, is .28.

Figure 9 Generic Greenhouse Configuration [44]



There are several methods used to heat greenhouses, such as this generic model. Typically, a heat distribution system is selected according to the operator's preference, rather than according to cost. Some systems are better than others, depending on the plants being grown. Gas-fired systems and geothermal systems operate very similarly. For conventionally heated greenhouses, a gas-fired boiler is used to heat water that is then circulated through a heating system. For geothermal heating, the hot fluids are transferred to the greenhouse heating system either directly or through a heat exchanger, depending on the quality of the geothermal fluids and the type of heat distribution system used. The costs for a gas-fired system will include a propane tank, a boiler, and pumps. The costs for a geothermal system will include piping from the resource, pumps, and possibly a heat exchanger. An overview and costs of different heat distribution systems are discussed below.

The assumptions made were that the available geothermal resource was 145°F and, though as much as 500 gpm of geothermal fluid is available, calculations were made based on 50 gpm being dedicated to this greenhouse so that the resource may be available for other direct-use applications, such as other greenhouses or aquaculture. Electricity cost was assumed to be 0.18$/kWh [45] and propane cost was assumed to be, $1.50 per gallon .[46] The costs for different heat distribution systems specific to the generic greenhouse model used in this assessment are shown in Table 10 and explained below. These are each unique heating options that would be chosen based most likely on operator preference and/or cost.

Table 10 Costs for Different Greenhouse Heating Systems

System Type	Capital Cost ($/ft^2)	Annual Maintenance ($/ft^2)	Annual Electricity ($/ft^2)	Total 10-year Cost ($/ft^2)
Unit Heaters	2.10	.03	.14	$3.80
Finned Pipe	6.60	.02	.00	$6.80
Bare Tubing	2.00	.01	.00	$3.00
Fan Coil Units	2.20	.03	.10	$3.50
Fan Coil Units with Bare Tubing	2.40	.03	.02	$2.90
Annual Propane Fuel Costs for Propane-Fired Systems ($/ft^2)	**5.80**		**10-year Cost ($/ft^2) for Propane Fuel**	**$58.00**

Unit Heaters are heating units that hang from the greenhouse structure at roof level. They consist of a coil that warm water flows through and a propeller fan to draw air through the coil to provide heating. Since copper tubing is typically used, a heat exchanger is necessary to avoid the deterioration that geothermal fluids can cause.[44]

Finned pipe is hung or laid throughout a greenhouse and allows passive heat transfer to the surrounding air. Finned pipe is designed for use with hot water at 200°F or higher, therefore a significant amount of pipe is necessary when used with a much cooler resource, such as is available for this project. Thus, the capital cost associated with finned pipe is much more expensive than the other heating systems.[44]

Bare Tube involves laying bare flexible plastic pipe throughout the greenhouse through which geothermal fluids typically flow. The pipe allows passive heat transfer to the surrounding air. In colder climates, significant quantities of tubing may be required to provide sufficient heating during peak cold weather.[44]

Fan coil units are similar to unit heaters, except that they are designed to be more efficient, especially with cooler resources. Though more expensive than unit heaters, fewer units may be necessary for the same greenhouse space.[44]

Fan coil units with bare tubing use bare tubing to provide around 65 percent of the total peak load and fan coil units to provide the remaining peaking load during colder weather. This combination may reduce capital and operating costs.[44]

As can be seen in Table 10 above, annual fuel costs for a propane-fired heating system are significantly greater than the capital and other operating costs over a 10-year period compared to other system options. The additional costs associated with a propane-fired boiler system are unknown, however, the estimated costs of intake and return piping for a 300 ft distance from the geothermal resource is $17,000[47] and the cost of a heat exchanger (not always necessary) is approximately $5,000.[48] There would be some additional cost for pumps, though they would be required for both geothermal and gas-fired systems. The $22,000 of additional geothermal capital costs is still less than the $29,000 annual cost for propane fuel alone, not including the capital costs of a boiler and propane system. Therefore, once I'SOT does construct their proposed geothermal electric plant and if there is a party interested in putting a greenhouse facility in Canby, it would be economically feasible to locate the greenhouse close to the plant and/or close to the geothermal resource and make use of the reduced energy expenses associated with geothermal heating.

Military Facility Heating

See the Military Facility Heating Section in Potential Projects in Region D – Imperial Desert for a description of the Sierra Army Depot project found in this region, but analyzed with other similar projects in the next section.

Geothermal District Heating in Bridgeport, CA

A geothermal district heating system for the town of Bridgeport, CA was studied with support from the Energy Commission in the early 1980's.[12] A test well was drilled to find a suitable resource to provide for district heating and small-scale electric production. However the resource discovered was not suitable to support either a district heating system, or a small-scale electricity power plant. Bridgeport Public Works, the agency in charge of the project, considered applying for funding to do additional testing to see if a suitable resource could be developed.[49] However, nothing has happened with the project in recent years and no one from the Bridgeport Public Works was available for comment.

Potential Projects in Region D – Imperial Desert

Salton Sea Restoration – Geothermal Desalination

The Salton Sea is a closed body of water that covers 365 square miles of Riverside and Imperial Counties. The current body of water was created in 1905 when a levee on the Colorado River broke and water flowed into the basin for 18 months. The water level and composition of the Sea is a balance between inflow from agricultural runoff and loss of water through evaporation. The runoff that provides the inflow to the Sea brings with it salts and other solutes. With no outlet, those salts from inflow compound on themselves and the salinity of the Salton Sea has been steadily increasing since it was formed. With continual increase of salinity, the Sea will eventually be unable to sustain wildlife.

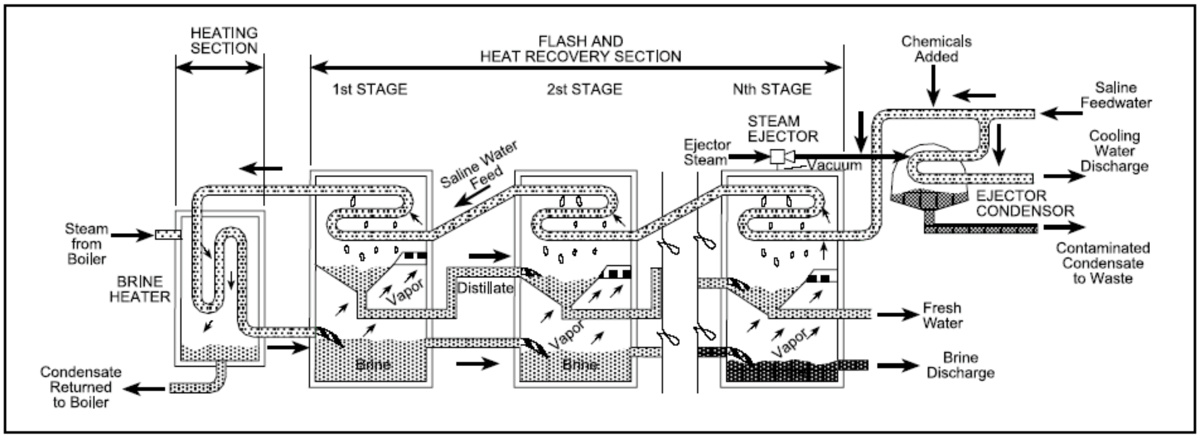
In 2003, a transfer of water rights was approved which will shift a significant portion of Colorado River water from agricultural use in the Imperial Valley to residential water use in San Diego County. This transfer is expected to substantially reduce the amount of inflow to the Sea. To mitigate the effects of that water rights transfer, the California Legislature has approved a program to develop a restoration alternative. Up to $300 million generated by the sale of Colorado River water could be available for Salton Sea restoration.

Desalination to reduce the salinity level of the Salton Sea is one proposed alternative for restoration. Desalination offers the ability to remove salt while losing very little water. A proposed desalination operation would use the waste steam from geothermal operations at the south end of the sea to remove salt from the water via a distillation process and either return the pure distilled water back to the sea to help control salinity and water levels, or sell the desalinated water to help pay for the restoration project. Such a desalination project would not provide a solution to the falling water level that will be a result of reduced inflow.

Desalination separates a stream of saline water into two streams, one with a low salinity (fresh water) and one that contains the remaining dissolved salts (brine). A thermal desalination system distills fresh water from salt water by boiling the salt water to produce water vapor, which is allowed to condense separately from the remaining brine. To make this process more economical, the pressure around the boiling water is reduced, which lowers the temperature at which the salt water will boil and produces water vapor along with the energy required to create the distilled water. For example, water boiled at a pressure equivalent to 20,000 ft in elevation boils at a temperature about 30°F lower than it would at sea level.[50]

A typical thermal desalination plant reduces the amount of energy needed for vaporization by using multi-pass boiling in successive vessels, each vessel operating at lower temperatures and lower pressures. The reduced pressure is caused by the condensation of water vapor in previous sealed chambers. Typically 8 tons of distilled water can be produced from one ton of steam.[50] An example of a thermal desalination system is shown in Figure 10.

Figure 10 Diagram of Thermal Desalination [51]



In addition to energy savings, the boiling of salt water at reduced pressures and reduced temperatures helps prevent the deposition of minerals (scale) in pipes. Several minerals in sea water dissolve readily in cooler waters but precipitate from solution near typical boiling temperatures. By bringing the salt water to boil at lower-temperatures, those minerals are prevented from precipitating out of solution and don't add scale to the insides of pipes. This reduces maintenance costs and increases the life of a system.[50]

The goal of the Salton Sea desalination project is to reduce the salinity of the Sea from the current level of 44,500 mg/L (milligram per liter) to less than 44,000 mg/L within 20 to 30 years. For this to be accomplished, 60 million tons of salt must be removed as well as the 4 million tons of new salt that flows in to the Sea each year. To meet these requirements, approximately 114 MGD (million gallons per day) of Sea water would have to be treated. A desalination project of this size would be constructed as part of Cal Energy Company's Unit 7 development effort, which if used for just electricity, would produce approximately 175 MW of electricity, or as dual use, would produce 80 MW of electricity and 2.85 million lbs/hr of 2-psig (217°F) steam.[52]

There are two stages proposed for building a desalination system for the Salton Sea. The first would be a facility capable of treating 20 MGD of Sea water that would be designed to operate off the 500,000 lbs/hr of waste steam available from CalEnergy Company's existing geothermal plants. The second would be a larger facility connected to the proposed Unit 7 at Cal Energy Company. The new Unit 7 would make much more efficient use of the geothermal steam; therefore there would not be significant "waste" steam available from this new power plant. Steam for desalination would have to be purchased from CalEnergy Company. The price used for calculations shown in this report is $3.48 per ton of steam; which is comparable to 7.5¢/kWh of electricity from the electric plant production.[52] The statistics and costs for the two desalination facilities are shown in Table 11.

Table 11 Statistics and Costs for Desalination Facilities [52]

	Existing Capacity w/waste steam	New Capacity w/CalEnergy Unit 7
Energy and Water Statistics		
Available Steam (million lbs/hr)	0.5	2.85
Peak Capacity (MGD)	20	114
Water Treated (M gallons/yr)	77,500	442,200
Distilled Water Returned or Sold (M gallons/yr)	62,000	353,500
Water Lost as Brine (M gallons/yr)	15,600	88,600
Salt Removed (million tons/year)	1.5	8.55
Capital Costs		
VTE Plant ($M)	82.3	420.6
Disposal Facilities ($M)*	27.1	148
Total Capital Cost ($M)	109.4	568.6
Annual Costs		
Operation, Maintenance & Replacement ($M)	2.9	7.9
Energy Costs ($M)**	1	40.6
Total for 30 Years (Present $M Value)	48	594
Total Cost of Salt Removal		
Total Cost of Salt Removal (Present $M Value)	157.4	1,162.6
Cost per Ton of Salt Removed	$3.37	$4.39

**Costs will vary depending on disposal method*
***Calculated at $3.48/ton of steam and 7.5¢/kWh.*

A recent report, Salton Sea Restoration: Draft Preferred Project Report dated April 2004, considered a better competing solution to geothermal desalination would be to build a causeway that bisects the Salton Sea in half. By doing so, one half of the Sea could be controlled to keep an appropriate water and salinity level, and the other half could have a reduced water level and increased salinity. Such a solution would allow for a saline lake on half the Sea that could support wildlife and recreation. Opportunities could also arise on the other half of the Sea, such as wetlands and areas available for geothermal development that are currently underwater. The estimated cost for this proposal is between $660 and $730 million with operating costs at around $8 million per year.[53] Such a project would have very significant impacts on the Sea, both positive and negative, which will have to be weighed by the authorities and agencies in charge of restoration, including the Salton Sea Authority, Bureau of Reclamation and others. If or when a restoration option will be chosen and implemented is unknown.

The information included in this section on Salton Sea Restoration is not meant to be a recommendation to the Energy Commission regarding methods of restoration or even if it should be restored, as that is not the purpose of this report. The Energy Commission is not involved in any significant way in the study of restoration methods for the Salton Sea. This report includes information on desalination of the Salton Sea using geothermal steam as an energy source, but there are other methods of desalination and other methods of restoration not described here. Geothermal desalination of the Salton Sea is included in this report as a possible geothermal project if it is chosen as the preferred method for restoration by the community and involved agencies.

Mineral Extraction from Geothermal Brine

CalEnergy Company currently operates 330MW of geothermal electricity production near the Salton Sea. The geothermal brine used in those plants has uniquely high levels of total dissolved solids (TDS), as well as rare, high concentrations of metals. CalEnergy Company currently extracts zinc and silica from the geothermal brine. The CalEnergy Company is also planning to expand to extracting manganese as well as considering the extraction of lithium and boron.[54]

Recently, CalEnergy Company has installed and begun using facilities at their Units 1 – 5 to remove 30,000 tons/year of zinc from the brine after it is flashed and used as steam energy for electricity production.[55] Flashing involves bringing high-temperature geothermal fluids up through wells. When exposed to the lower atmospheric pressures at the surface, the fluids “flash” to steam. Worldwide, nearly 6 million tons of zinc is used each year, so the 30,000 tons produced by CalEnergy Company should not have any significant effect on the market price of zinc. Though the costs for the zinc extraction process are not available publicly, CalEnergy Company claims that their process for zinc extraction is competitive to other methods of obtaining zinc.[56]

The use of geothermal brine as a metal source eliminates the need for mining, whether underground or surface, which has more significant effects on the environment than extraction from geothermal brine. CalEnergy Company’s zinc recovery is one the cleanest and most environmentally-friendly zinc recovery operations in the world.

CalEnergy Company may expand their extraction operations to include manganese at Units 1 – 5, where zinc is currently extracted. A pilot manganese extraction process was tested in cooperation with the Energy Commission.[55] Other options for expanding their mineral extraction processes could include; extracting zinc at their proposed new Units 6 & 7, extracting manganese at their proposed new Units 6 & 7, and expanding all extraction processes to include lithium and boron.[54]

Zinc prices have recently been fluctuating between $.35 and $.50 per pound. Zinc is used to form numerous alloys with other metals and for other uses in industry.[57]

Manganese prices range from $.70 to $1.00 per pound depending on quality.[58] Manganese is used in steel production, as a depolarizer in dry cells, to "decolorize" glass that is colored green by impurities of iron, and other uses in industry.[59]

Lithium metal is priced at about $300/lb. Lithium, as a metal with the highest specific heat of any solid element, is used in heat transfer applications. It is also used in dry cell batteries, as an alloying agent, and in other chemical and engineering applications.[60]

The price of Boron is roughly $.45/lb.[61] Boron has uses in pyrotechnic flares to provide a distinctive green color and in rockets as an igniter, in commercial chemical compounds, as an aerospace material, and in other chemical and industrial uses.[62]

Military Facility Heating

In 2003, the Department of Defense completed a report evaluating the potential for geothermal use on lands under the control of the military services. The report, Geothermal Energy Resource Assessment on Military Lands[11], examined the possibility for developing geothermal utility-grade electricity production and direct-use. Thirty-five facilities were selected for review out of the more than 100 installations in the western United States. This selection was based on having geothermal resources of at least 120°F (or temperature gradients greater than 2°F/100 ft) and well depths less than 3000 ft within 5 miles of structures. The report recommended working with managers of these facilities to determine if meeting energy demands through geothermal direct-use fits their long term energy and environmental strategies. From there, next steps would include determining the characteristics of wells and groundwater in the area and then developing a conceptual design for a heating and/or cooling system, including approximate flow rates and an identification of buildings to be included in the system.[11]

The report identified four military facilities in California with the potential for direct-use heating and/or cooling. Space heating typically requires a geothermal resource of at least 120°F, while space cooling requires resources at least 230°F. Since none of the facilities in California have resources warm enough to support geothermal space cooling, the information included in this report will only focus on space heating.

In Region C – Sierra Cascades, one facility, the Sierra Army Depot, was identified. In Region D – Imperial Desert, three facilities were identified; Naval Air Weapons Station (NAWS) China Lake, Chocolate Mountains Aerial Gunnery Range, and Twentynine Palms United States Marine Corps (USMC) Air Ground Combat Center.[11] The facility at Sierra Army Depot was selected as one of the top four sites in the nation for direct-use heating and/or cooling. This selection was based on having current geothermal resources greater than 200°F at a depth less than 3000ft within five miles of structures.

To assess the potential for geothermal space heating systems on military facilities, a basic model was created and an economic analysis model developed by the Geo-Heat Center was applied.

For each site, average annual Heating Degree-Days (based on 65°F) were calculated based on 10-years of daily high and low temperature readings at nearby weather stations. The lowest temperature over that 10-year span was recorded, and 75 percent of the difference between 65°F and that low was used for calculating a peak load. As well as weather data, the temperatures and depths of wells used in the above mentioned report for assessment are included to estimate well and system construction costs. These data are shown in Table 12 below.

Table 12 Well and Weather Data for Military Facilities

Facility	Well Depth	Well Temp	Degree-Days[63]	10-Year Low[63]	Weather Station
Sierra Army Depot	1115 ft	225°F	6170°F	-15°F	Susanville, CA
China Lake	600 ft	136°F	1794°F	10°F	Trona, CA
Twentynine Palms	1095 ft	153°F	1965°F	21°F	Daggett, CA
Chocolate Mountains	827 ft	113°F	1263°F	25°F	Brawley, CA

For each site, a generic base load to meet the annual needs of five 5000 ft^2 buildings was first used to provide a baseline for assessments. Calculations for the heat loads of these buildings were made assuming an insulation factor (Thermal Resistance, R-factor) of R2.5. The units for an R-factor are [(ft^2*°F)/(Btu/hr)]. R2.5 was an estimate to account for windows, doors and older construction. As this is just an estimate, the R value for facilities on these sites could be higher or lower. Common R values are: new home walls (not including windows & doors), R11; brick, R4; concrete block, R2; 1" wood siding, R1; glass, R1; and stagnant air, R0.15.[64] An exposed surface area of 8000 ft was used in calculations, which are shown in Figure 11. The variables used below include: T_{min}, the 10-year low temperatures shown in Table 12; Q, heat; t, time; and ΔT, temperature difference.

Figure 11 Heat Load Calculations

$$\Delta T = (.75)\cdot(65°F - T_{\min})$$

$$Building\ Peak\ Load\ (BTU/hr) = \frac{Q}{t} = \frac{Area\cdot\Delta T}{R} = \frac{(8000\ ft^2)\cdot\Delta T}{2.5\frac{ft^2\cdot°F}{BTU/hr}} = 3200\cdot\Delta T$$

$$Total\ Peak\ Load = (5\ Buildings)\cdot(Building\ Peak\ Load) = 16{,}000\cdot\Delta T$$

$$Loss\ per\ Degree-Day = \frac{Area\cdot(1°F)}{R}\cdot 24(hrs/day) = 76{,}800\frac{BTU}{Degree-Day}$$

$$\begin{aligned} Annual\ Load &= (Loss\ per\ Degree-Day)\cdot(Degree-Days/Year)\cdot(5\ Buildings) \\ &= 384{,}000\cdot(Degree-Days/Year) \end{aligned}$$

$$Load\ Factor = \frac{Annual\ Load}{(Peak\ Load)\cdot(365days/year)\cdot(24hrs/day)}$$

Table 13 Heat Load Calculations

Facility	ΔT	Peak Load	Annual Load	Load Factor
Sierra Army Depot	60°F	960,000 Btu/hr	2,370 MMBtu	0.28
China Lake	41°F	660,000 Btu/hr	690 MMBtu	0.12
Twentynine Palms	33°F	528,000 Btu/hr	756 MMBtu	0.16
Chocolate Mountains	30°F	480,000 Btu/hr	486 MMBtu	0.12

The system cost estimates shown below are calculated using a model developed by the Geo-Heat Center.[47] The model estimates the costs of a geothermal space heating system including capital costs, such as well construction and piping (distance from well is estimated to be 300ft). Electricity costs used in this model are $.18/kW, which is estimated from the Energy Commission's website.[45] An interest rate of 7 percent is included in capital costs divided over the estimated 20 year life span of the system. The Geo-Heat Center model also provides estimated costs of a gas-fired heating system to provide the same heating capacity. Due to the assumption that natural gas is not available on these sites, propane was assumed as the fuel used for a gas-fired heating system. The cost of propane used is $1.50 per gallon, which is estimated from the U.S. Energy Information Administration's winter 2003-2004 average prices.[46] These prices were similar to the current prices offered by a local propane provider.[65]

When the Geo-Heat Center model is applied and a comparison between a gas-fired system and geothermal heating system is made, the heat load of the generic five 5000 ft^2 building models used does not result in heat loads large enough to result in adequate savings for a simple payback for a geothermal system at any of the facilities except Sierra Army Depot Region C. For the Sierra Army Depot, the payback period is shown in Table 14. For the facilities for which the generic heat load does not provide adequate savings for simple five year payback, the factor by which the load must be increased to provide such savings is shown in Table 14. These calculations are shown for a system without a re-injection well and one with a re-injection well. The costs of converting current building heating systems are ignored, since the number of buildings and types of heating systems used are unknown. It is very possible that these facilities currently use a hydronic heating system, which would have very low capital costs associated with conversion.

Table 14 Payback Periods for Military Facility Heating

Facility	No Injection Well	Required Flow	With Injection Well	Required Flow
Sierra Army Depot	**Payback in 3 years**	32 gpm	Payback in 7 years	32 gpm
For 5 year payback	*Load of .72 X Generic Load*	*23 gpm*	*Load of 1.2 X Generic Load*	*39 gpm*
China Lake	Payback in 14 years	32 gpm	Does Not Provide Payback	
For 5 year payback	*Load of 1.6 X Generic Load*	*52 gpm*	*Load of 1.6 X Generic Load*	*80 gpm*
Twentynine Palms	Does Not Provide Payback		Does Not Provide Payback	
For 5 year payback	*Load of 2.3 X Generic Load*	*73 gpm*	*Load of 4 X Generic Load*	*127 gpm*
Chocolate Mountains	Does Not Provide Payback		Does Not Provide Payback	
For 5 year payback	*Load of 2.8 X Generic Load*	*88 gpm*	*Load of 4.7 X Generic Load*	*150 gpm*

These peak loads assume that a resource can be developed at the depths and temperatures shown in Table 12 and can provide the required flows shown above in Table 14 in gallons per minute (gpm). The estimated costs for geothermal systems at each site compared to a gas-fired system serving the heat load required for five year payback are shown below for each site. Because of its properties, the Sierra Army Depot is also shown with the noted 3 year and 7 year payback periods.

Sierra Army Depot with Generic 5-Building Load	Without Re-Injection (3 Year Payback Period)	With Re-Injection (7 Year Payback Period)
Design Load	960,000 Btu/hr	960,000 Btu/hr
Geothermal Capital Costs	$127,000	$215,000
Geothermal Total Cost ($/MMBtu)	$6.70	$10.30
20-year Geothermal Cost In 2004 Dollars	$318,000	$488,000
Gas-Fired Capital Costs	$13,300	$13,300
Gas-Fired Total Cost ($/MMBtu)	$22.50	$22.50
20-year Gas-Fired Cost In 2004 Dollars	$1,066,000	$1,070,000

Sierra Army Depot with 5 Year Payback	Without Re-Injection	With Re-Injection
Design Load	693,000 Btu/hr	1,165,000 Btu/hr
Geothermal Capital Costs	$127,000	$214,000
Geothermal Total Cost ($/MMBtu)	$9.00	$8.60
20-year Geothermal Cost In 2004 Dollars	$306,000	$492,000
Gas-Fired Capital Costs	$10,700	$15,600
Gas-Fired Total Cost ($/MMBtu)	$21.60	$22.50
20-year Gas-Fired Cost In 2004 Dollars	$734,000	$1,290,000

China Lake with 5 year Payback	Without Re-Injection	With Re-Injection
Design Load	1,069,000 Btu/hr	1,634,000 Btu/hr
Geothermal Capital Costs	$88,000	$136,000
Geothermal Total Cost ($/MMBtu)	$10.50	$10.00
20-year Geothermal Cost In 2004 Dollars	$236,000	$344,000
Gas-Fired Capital Costs	$14,500	$20,600
Gas-Fired Total Cost ($/MMBtu)	$23.50	$23.40
20-year Gas-Fired Cost In 2004 Dollars	$528,000	$804,000

Twentynine Palms with 5 Year Payback	Without Re-Injection	With Re-Injection
Design Load	1,202,000 Btu/hr	2,095,000 Btu/hr
Geothermal Capital Costs	$127,000	$222,000
Geothermal Total Cost ($/MMBtu)	$9.90	$9.50
20-year Geothermal Cost In 2004 Dollars	$344,000	$558,000
Gas-Fired Capital Costs	$16,000	$25,200
Gas-Fired Total Cost ($/MMBtu)	$23.10	$22.90
20-year Gas-Fired Cost In 2004 Dollars	$780,000	$1,340,000

Chocolate Mountains with 5 Year Payback	Without Re-Injection	With Re-Injection
Design Load	1,317,000 Btu/hr	2,252,000 Btu/hr
Geothermal Capital Costs	$106,000	$183,000
Geothermal Total Cost ($/MMBtu)	$10.60	$10.10
20-year Geothermal Cost In 2004 Dollars	$294,000	$478,000
Gas-Fired Capital Costs	$17,000	$26,700
Gas-Fired Total Cost ($/MMBtu)	$23.50	$23.30
20-year Gas-Fired Cost In 2004 Dollars	$650,000	$1,100,000

Judging from the calculations shown above, it is recommended that a geothermal space heating system at the Sierra Army Depot facilities be further investigated. If heat loads similar or greater than those of the generic five buildings used for these calculations can be identified, this project has the possibility of being economically feasible. More needs to be known about this project, including: whether a resource can be developed close to the facilities to be heated (the geothermal resource will have to be closer than the criteria of five miles used in the Geothermal Energy Resource Assessment on Military Lands report), whether the facilities make up a heat load large enough to support space heating, and what types of heating systems are currently used and what would be the costs associated with converting these heating systems to use geothermal space heating.

Although not as likely, if heating loads equaling those providing five-year payback for the other three sites are present, geothermal space heating should also be further investigated at those sites. And, there should be some consideration given to whether a payback period of more than five years would be appropriate for a Department of Defense project. It could be of benefit to have a taxpayer subsidized capital investment in geothermal heating systems. Natural gas and propane costs will continue to escalate and our military requirement is not going to disappear. And, future plans for these military sites discussed will impact the likelihood of potential for geothermal development.

Algae Farm Pond Heating

Earthrise Nutritionals is a 25 year old company that provides nutritional supplements to the natural foods market. Their main product is dried Spirulina, (common blue-green microalgae). Their company grows the algae at a farm facility in the Imperial Valley in several 5000 square meter ponds that cover over 100 acres. These ponds are fed by the Colorado River where trace minerals are added and carbon dioxide is bubbled in to help in the growth of the algae.[66]

It was suggested by George Ray, a nearby aquaculture grower and geothermal user, that geothermal fluids would be beneficial to their operation. Earthrise shuts down operations for five months during the winter time due to the cooler weather, which hinders algae growth. Mr. Ray believes geothermal resources could provide heating to Earthrise facilities to allow growth year round by introducing geothermal waters directly into the ponds. Further, he believes that the high level of carbon dioxide in the geothermal fluids, which is a hindrance for his fish production, could be highly beneficial to the growth of algae. Plants use carbon dioxide for photosynthesis rather than oxygen.[24]

Representatives at Earthrise confirmed that they would be interested in learning about the possible benefits to their operations by using geothermal fluids. They are interested in the costs associated with geothermal resource use and whether it could be cost effective. However, they are also concerned with providing proprietary information about their growing process for a public report.[67] Working directly with representatives from the Energy Commission could possibly help alleviate their concerns.

Geothermal heating could be used for all of their ponds through the winter months, or for just a few to keep a “seed” amount of growth through the winter to allow for a shorter time to bring production to full capacity during the warmer months. The geothermal fluids could provide benefits to operations year round if the carbon dioxide content of the fluids is found to be beneficial. However, some consideration will have to be given to other chemical constituents of geothermal fluids, since the fluids would be used for growing food meant for human consumption.

Triple Uses at Heber Geothermal Power Plant

Although not necessarily a well-developed project, as there is no present user to develop the currently available geothermal resource, the idea of triple uses of geothermal fluids was a concept developed during a conversation with Sergio Cabanas, a member of the Geothermal Association of Imperial County and employed with the Ormat Geothermal Electric Power Plant in Heber, CA. At the Heber plant at which he is employed, Mr. Cabanas discussed how the majority of the geothermal fluids used in the plant are re-injected into the wells to help maintain proper fluid levels in the aquifers. However, a certain percentage of the water used for electric power production is not re-injected, but ends up being purified during the generation process to better-than drinking water quality standards, except for a few solutes. Mr. Cabanas discussed how that warm water could be used in a direct-use application. Aquaculture was considered a good candidate, since there are other similar aquaculture applications in the area that use fluids from geothermal wells to provide both domestic water and heating.

Since the water is of relatively high quality, it could be possible to also use the geothermal fluids used to heat the aquaculture ponds for irrigation in the agricultural fields that surround the power plant. As stated by Kevin Rafferty in GRC Geothermal Bulletin, "'Dual use' of water is considered by many as a model for future aquaculture development." [6] The waste water from aquaculture could be beneficial to agriculture not only as a source of water (which is becoming more scarce in the Imperial Valley), but also due to the fertilizing properties of the by-products from fish.

Cascading uses of geothermal resources, such as proposed here, would make efficient use of a warm water resource that is currently disposed of as waste water after electricity production.

New Spa Construction in Desert Hot Springs

According to Mike Woods – the Division 2 Director of the California Department of Conservation, Division of Oil, Gas & Geothermal – recent interest in geothermal direct-uses has primarily been focused on commercial hot spring spas. His most recent permit application was for a hotel hot spring spa in the city of Desert Hot Springs, a city that already has direct-use geothermal applications (a hot springs-supplied spa and a space-heating facility) .[2]. The applicant was unreachable for more information, as the phone number for the hotel was disconnected, possibly due to renovations. Growth in the use of geothermal energy for commercial hot spring spas is not expected, as descried in the application section of this report.

Direct-use in the City of Twentynine Palms

In 1986, the Energy Commission funded a Geothermal Resource Assessment for Twentynine Palms, California. The project sought to find and develop a geothermal resource in the city of Twentynine Palms. Testing of potential resource areas was done and the report recommended a site for additional geothermal surveying. The report suspected a resource of up to 160°F at about 400 feet in depth. The 1986 report recommended using geothermal energy in Twentynine Palms for space heating and cooling and considered its use practical, feasible and would help conserve non-renewable energy. The report recommended that a geothermal resource be used for both heating and cooling, since there is a more significant cooling load in the area than there is a need for heating. Simple calculations in the report suggested a payback period from 11 to 17 years.[68]

As a follow up to the 1986 report, the drilling of geothermal well, TNP-1, was begun with assistance from the Energy Commission. The only documented testing was done just 18 hours after drilling to a depth of 451 feet with a near-bottom hole temperature of 123°F.[69] However, the well was not completed within the time constraints of the project and no additional information was provided on the well or any further development of the well in the 1985 report. When the city of Twentynine Palms was contacted for more information, the only information available on geothermal resources were the reports completed for the Energy Commission.[70] Therefore, it is possible that there is an opportunity for direct-use development in the city of Twentynine Palms, but there is no current development or activity.

Potential Projects in Region E – South Coast

Direct-use in the City of Paso Robles [71]

On December 22, 2003, an earthquake caused a hot spring to appear in the City of Paso Robles City Hall parking lot. The spring, and the necessary mitigation efforts that have been taken, resulted in a very large hole in what was the city hall south parking lot. Initially, the water from this spring flowed into the city sewer system. Concerned with the effects this water may have on the public sewers, the city redirected the flow into the Salinas River. Currently the 360 gallon per minute, 112°F resource remains un-used and diverted into the river. Although worried about the effect on the Salinas River habitat, regulatory agencies have temporarily allowed the geothermal fluids to flow directly into the river. However, a permanent method of fluid disposal must be found.

Other, smaller springs have also appeared in the city since the earthquake. Mapping of the springs has shown that they are most likely the result of intersecting north-south and northwest-southeast fractures or faults. City officials have chosen to allow the City Hall spring to flow unchecked, since the faults or fractures pass under several other important structures in the city. The city does not wish to risk the appearance of a spring in a more damaging location as a result of capping or reducing the flow of the City Hall spring.

In early 2004, the City of Paso Robles applied to the Energy Commission for assistance in assessing the new resource, reviewing feasible geothermal applications, and determining a proper way to dispose of the geothermal waters. An application, accepted and approved by the Commission, will allow the City to better understand the geothermal resource that lies beneath. The proposed project will also attempt to identify beneficial uses of the hot water resource. The local community will be petitioned for their ideas on potential uses. The ideas suggested by the community, as well as those already proposed by the city, will be ranked and the most promising uses will be studied further. Current possible uses of the resource include:

1. a flow-through pool at the Paso Robles Inn
2. heating the Paso Robles Municipal Pool

3. digester heating for the Paso Robles waste water treatment plant
4. space heating at the City Hall & Library
5. space heating at the city Safety Center

A proper disposal method for produced fluids in the Paso Robles City Hall parking must be implemented. The two methods currently considered are: using a reinjection well, or treating the water to allow it to be used for irrigation or drinking. Reinjection is generally expensive, which includes the cost of constructing a reinjection well and the energy required to reinject the water into the aquifer. Energy needs are especially high when the formation produces artesian fluids (non-pumped), which is the case in Paso Robles. A reinjection well at the Paso Robles Inn will be monitored to help gather data useful in determining the cost of a reinjection well for the City Hall hot spring. The alternative to reinjection is to treat the water and make it useable for irrigation or domestic consumption. The water chemistry has been evaluated and can be improved through a variety of treatment options. As part of the Paso Robles / Energy Commission project, the most economical disposal method will be determined. Useful heat may be available prior to disposal.

In the case of the Paso Robles City Hall hot spring, a resource is presently available and the geothermal fluids must be disposed of in some manner, regardless if the hot spring is used in direct-use applications or not. A significant factor that will affect whether or how the resource is used for direct-uses is the cost of transporting the geothermal fluids from the source to the site(s) of use(s) and then to the disposal site. The specific site(s) of direct-use applications will significantly affect its outlook at as a viable application. The best site would minimize the amount of pipe that must be laid for transport among the source, use, and disposal.

Two private spa-type resorts exist within the city of Paso Robles that utilize geothermal fluid that is produced from wells drilled for that purpose. In the past, there has been considerable interest in using the hot water resources that lie beneath the city, but a limiting factor has been the lack of understanding of the resources disposal, and adequate project funding. With the formation of the City Hall spring, these issues will have to be resolved, which could improve the possibility for new geothermal projects in the City ofPaso Robles.

Huntington Beach Direct-use of Oil Processing Wastewater

In the early 1980's, the city of Huntington Beach with the Energy Commission support began a study looking at the possible uses of waste heat fluids from oil drilling and refining operations in the area. Huntington Beach overlies one of the largest oil fields in California. In 1981, the total production from the oil field beneath Huntington Beach broke one billion barrels, making it the third most productive oil field in California. In just that year, 10 million barrels of oil were produced. Of significance however, are the 11 barrels of hot water extracted for every barrel of oil produced. This tremendous volume of water, over 11,000 gallons per minute in just one of the processing plants, is typically between 110°F and 175°F. There is a unique opportunity for the development of this geothermal resource. A great quantity of warm water is produced in the course of normal oil operations and there is no need to develop a well, which is usually necessary with typical geothermal resource developments. Also, these oil operations and associated warm water resources are near urban development, providing a number of potential users in the immediate area.[72]

The report developed from these studies, Huntington Beach Energy Series, Report #6: Low Temperature Geothermal Resources in Huntington Beach, concluded that this resource could best be used by space and water heating; particularly through district heating projects. It recommended further technical and economic feasibility analyses and continued city participation. Recommendation was to use geothermal fluids in new development or redevelopment projects, but the report did not hold out the possibility of retrofitting current buildings and facilities.[72]

It seems no further action was taken from the recommendations of this report. City officials that were involved in the report are no longer employed and contacts with the city were unable to identify anyone who had knowledge of this report or the available resources identified in the report.[73] It was confirmed with Energy Commission staff that no further activity was taken with this project.[74]

Expansion of Direct-use at the San Bernardino Geothermal District Heating System

In the early 1980's, the San Bernardino Municipal Water District undertook a project to utilize geothermal energy for use in their Wastewater Treatment Plant. With the help of the Energy Commission, a geothermal well was developed and the resource was used to provide heating in the wastewater treatment process. When the 1983 report, Direct Use of Geothermal Energy at the San Bernardino Wastewater Treatment Plant [75] was completed, one anaerobic digester had been converted over to use geothermal heat as its energy source. There was an expected expansion to use geothermal energy in two other digesters.

The annual energy needed to heat one digester was 4.4 Billion Btu. At the time, by using geothermal energy the water district was saving $29,500/year (1983 dollars). Natural gas was costing the water district 315 percent that of geothermal heating. At that rate, they expected to recover all investment costs in less than 10 years.

In 2004, the San Bernardino Municipal Water District was contacted to update the status of theis geothermal heating project and if there are still plans to increase the use of geothermal resources in their wastewater treatment facility. Geothermal heating is being used for space heating in the wastewater treatment plant and for some pre-heating in the wastewater treatment process itself; but there are no plans for expanding direct-uses in the facility. The water district has begun using natural gas (more efficiently than before) to provide a more significant heating role for their treatment processes. [76]

The San Bernardino Water Department continues to operate a geothermal district heating system for both government and commercial users. In the past 10 years, the department has lost some customers, but has recently added new customers to the system, keeping their geothermal customer base relatively stable. The Water Department has the potential to take on additional customers in the future and continues to actively market their district heating system.

Project Ratings

This Review of Potential Geothermal Projects section contains basic information on all selected projects. To determine which of the 17 projects should have more detailed information gathered, an initial rating was completed; the results are shown in Table 15. Additional information was collected for the projects with the highest likelihood for near-term development based upon the initial ratings. For those projects, detailed information is included in the projects' descriptions and when possible, basic engineering and/or economic assessments were included.

Once the additional detail and analysis gathering was competed, another rating based upon the detailed analysis was completed. Those ratings are shown below in Table 16.

Initial Ratings

The initial ratings of the 17 identified projects were based upon four simple questions. The ratings given are based on information collected from experts and project managers. Higher scores yield a higher rating. The questions are:

- What is the likelihood that a geothermal resource providing the necessary heat requirements for the application is available, now or in the near future? The ratings are as follow:

5, There is a known geothermal source that meets the requirements (temperature, flow, clarity, distance from project) of the application.
3-4, There may be a known geothermal source, but with unknown properties. Or, there is not a currently available geothermal source for the project, but there are resources in the surrounding area that meet the requirements of the application. The difference between a 3 and 4 is subjective, based on interviews with experts and project managers.
2, Information about geothermal sources in the area is not available.
1, Resources in the vicinity of the project are known not to meet the needs of the application.

- Is there a geothermal direct-use expert involved in this project? The ratings are as follows:

5, There is a direct-use expert personally invested in the project.

3-4, There is a geothermal expert, but they may not be personally invested in the success of the project. The difference between a 3 and 4 is subjective, based on interviews with experts and project managers.
2, There is not a geothermal expert involved with the project, or their involvement is unknown.
1, It is known that no one is pursuing this project, geothermal expert or otherwise.

- Is there an expert in the industry involved in this project to which geothermal direct-use will be applied? The ratings are as follows:

5, There is an industry expert personally invested in the project.
3-4, There is an industry expert, but they may not be personally invested in the success of the project. The difference between a 3 and 4 is subjective, based on interviews with experts and project managers.
2, There is not an industry expert involved with the project, or their involvement is unknown.
1, It is known that no one is pursuing this project, industry expert or otherwise.

- Is there a party or entity currently interested in pursuing this project? This is a simple question that is very important to the likelihood of near-term development of a project. The ratings are as follow:

5, There is a "hero" involved in this project. The importance of a hero is discussed earlier in the report and is a significant factor in the success of a direct-use project.
3-4, There are parties pursuing the project, but no definitive "hero" involved. The difference between a 3 and 4 is subjective, based on interviews with experts and project managers.
1-2, There is no one pursuing this project, or it is unknown if someone is pursuing this project. The difference between a 1 and 2 is subjective, based on interviews with experts and project managers.

These initial rankings determined which projects further information would be pursued and a detailed assessment would be completed. Table 15 summarizes the results.

Table 15 Initial Project Ratings

Projects	Geothermal Resource	Geothermal Expert	Industry Expert	Interested Party	**Average**
Mineral Extraction from Geothermal Brine	5	5	5	5	**5.0**
Aquaculture in Canby, CA	4	5	5	5	**4.8**
Greenhouse Heating in Canby, CA	4	5	3	5	**4.3**
Salton Sea Geothermal Desalination Restoration	5	4	4	4	**4.3**
Direct-use In Paso Robles, CA	5	4	4	4	**4.3**
Mammoth Lakes District Heating	4	4	4	4	**4.0**
Military Facility Heating: Sierra Army Depot	4	4	4	3	**3.8**
Military Facility Heating: China Lake	4	4	4	3	**3.8**
Military Facility Heating: Twentynine Palms	4	4	4	3	**3.8**
Military Facility Heating: Chocolate Mountains	4	4	4	3	**3.8**
New Spa Construction at Desert Hot Springs, CA	3	1	3	3	**2.5**
Triple Use at Heber Geothermal Power Plant	5	1	1	1	**2.0**
Algae Farm Pond Heating	3	1	4	1	**2.3**
Direct-use in Twentynine Palms, CA	4	1	2	1	**2.0**
Direct-use in Huntington Beach, CA	4	1	1	1	**1.8**
Bridgeport District Heating	2	1	1	1	**1.3**
San Bernardino Wastewater Treatment Plant	Abandoned				

The 10 highest scoring projects in the table above were selected for more detailed analysis. For these projects, additional information was gathered and included in the project summaries shown in this Review of Potential Geothermal Projects section. For applicable projects, basic engineering and/or economic assessments were completed. Project summaries above include information gathered in the detailed assessments.

Final Project Ratings Based on Detailed Assessment

Several factors, developed through the research conducted for this report, are assumed to positively influence the likelihood of near-term development of a geothermal direct-use project. These factors are:

- The availability of geothermal resources, including methods to dispose of geothermal fluids
- Expertise in direct-use geothermal energy and the industry/business to which it is applied
- A desire to implement direct-use
- A “hero” who is personally invested who can push a project through many of the hurdles inherent with geothermal direct-use
- Past direct-use experience, especially with similar applications, at the site and by the parties involved
- Cost savings compared to other fuel alternatives, provided that there are alternatives
- Ability to meet the economic requirements imposed on the project
- Ability to overcome political and bureaucratic barriers

Final ratings of the projects included in the detailed assessment, are based on the information gathered and on the results of analyses performed for this report. This overall rating is the assessment of the projects based on the assumptions given above. An explanation of these ratings follows Table 16.

Another important consideration when judging a potential geothermal direct-use project is the cash-flow potential of a particular project in terms of its added value to the local economy beyond energy savings. Cash-flow potential was not considered in these rankings. For instance, a geothermal greenhouse that sells potted plants may have annual gross receipts that range from $400,000 to $800,000 per acre, hire four to eight employees per acre, and have a major net energy cost savings compared to fossil fuels use. The cash flow into the local economy from a geothermal greenhouse may far exceed that generated by a district-heating system for a concentration of government buildings and/or schools that is coupled with nearby residential users. The same advantages exist for aquaculture and industrial uses of geothermal.[14]

Table 16 Final Rankings of Projects Included in Detailed Assessments

Projects	Detailed Assessment Ratings
Mineral Extraction from Geothermal Brine	**5**
Aquaculture in Canby, CA	**4**
Greenhouse Heating in Canby, CA	**3**
Direct-use in Paso Robles, CA	**3**
Mammoth Lakes District Heating	**3**
Salton Sea Geothermal Desalination Restoration	**2**
Military Facility Heating: Sierra Army Depot	**2**
Military Facility Heating: China Lake	**1.5**
Military Facility Heating: Twentynine Palms	**1**
Military Facility Heating: Chocolate Mountains	**1**

Explanation of Project Ratings

The explanations below support the Detailed Assessment ratings shown in Table 16. The ratings are out of five.

Mineral Extraction from Geothermal Brine

This project has excellent potential, as it is a continuation of the zinc extraction that is currently on-going at CalEnergy Company's Imperial Valley geothermal power plant facilities. According to CalEnergy Company, the current zinc extraction is economically competitive in the marketplace. CalEnergy Company has plans to expand its mineral extraction to at least manganese in the near future with interest in lithium and boron as well. The rating given to this project is high due to the strong potential for near-term implementation as well the fact that current zinc production is competitive in the market of mineral production; the desire to expand to other minerals is market driven as well. This project is given a rating of 5 out of 5 because of this high potential.

Aquaculture in Canby, CA
This project has good potential, as there is a geothermal “hero” involved with the project, who has gone through the entire process of implementing a direct-use project. The project also has a user, who has expertise in the industry of aquaculture and geothermal direct-use with aquaculture. However, the project is dependant on the completion of a small geothermal electric plant for I’SOT. Therefore, a significant factor that affects the implementation of aquaculture in Canby is the likelihood of I’SOT’s geothermal electric plant project being completed and this likelihood is relatively unknown. It could be of interest to the Energy Commission that fostering the development of I’SOT’s geothermal electric project could have the benefit of providing additional direct-use resulting from such a project. It is possible that wastewater from the Canby district heating system could be used in the event that a geothermal electric facility is not constructed. The strong project leadership in both geothermal direct-use and aquaculture outweigh the unknown likelihood of a resource being developed. Therefore, this project is given a rating of 4 out of 5.

Greenhouse Heating in Canby, CA
This project has potential, as there is a geothermal “hero” involved with the project, who has gone through the entire process of implementing a geothermal direct-use project. However, there is currently not an identified greenhouse industry expert involved with the project. The cost of energy savings could be significant enough to influence local greenhouse operators to expand their operations to make use of the energy. The project is dependant on the completion of a small geothermal electric plant for I’SOT. Therefore, a significant factor that affects the implementation of greenhouse heating is Canby is the likelihood of I’SOT’s geothermal electric plant project being completed and this likelihood is relatively unknown. It could be of interest to the Energy Commission that fostering the development of I’SOT’s geothermal electric project could have the benefit of providing additional direct-uses resulting from such a project. The very positive aspects of the strong direct-use leadership of Dale Merrick and the economic benefits of using geothermal heating for greenhouses in that region are tempered with the facts that a current greenhouse user has not yet been identified and the likelihood of a resource being developed is unknown. Therefore, this project is given a rating of 3 out of 5.

Direct-use in The City of Paso Robles, CA
A project in The City of Paso Robles has potential, resulting primarily from necessity. Past barriers to geothermal direct-uses in the area include the lack of understanding of the geothermal resources available, the cost of developing resources, and unknown costs and methods of disposing of geothermal fluids. Now that a significant warm water spring has developed in the center of the city, much of these past barriers will have to be addressed. A proper disposal method for the fluid from this spring must be implemented. As part of an Energy Commission supported project, the best method for disposal will be determined. Another goal of the Commission-supported project is to determine a direct-use(s) of this resource. There are imposed requirements on the City to do something with the fluids from this

spring and a study will evaluate uses for this resource. There is potential that a feasible direct-use project will be identified that will be implemented in the near-future. Despite the fact that an end-use of the geothermal resource is not yet identified, the involvement of the Commission and the unique necessity that something must be done with these fluids, result in the project being given a rating of 3 out of 5.

Mammoth Lakes District Heating

This project has potential, as shown in the feasibility study completed by FVB Energy. It seems that the biggest barrier to this project thus far has been its size and the high initial capital costs associated with its implementation. The eventual energy savings, as well as the environmental and community benefits accruing from full implementation of direct-use in Mammoth Lakeswould be significant in the long term. Reliable and inexpensive space heating, as well as sidewalk and road snow-melting would make Mammoth Lakes a uniquely attractive community. However, finding methods of paying for such an energy system is difficult. Just financing the first phase of providing district heating to nearby public users would involve canceling the original plans of using waste heat fluids from the nearby Casa Diablo power plant, reducing the number of users initially included and the capability to develop a suitable resource much closer to the community. Even though this project has been considered for more than twenty years, it should still be near the top of the list of important geothermal projects that could lead the way in displaying the many benefits that geothermal energy can provide. Due to the FVB Energy assessment, the rating given to the project is weighted by the expectation that an economically feasible method of implementing the first phase of district heating in Mammoth Lakes can be found. However, the rating must acknowledge the unknown potential for developing a geothermal resource close to the community. Because of these factors, the project is given a rating of 3 out of 5.

Salton Sea Geothermal Desalination Restoration

This project has significant expertise involved in both geothermal resource uses and desalination, as well as significant government involvement. The project would operate using steam from CalEnergy Company's geothermal operations at the Salton Sea, which means the project would benefit from their wealth of geothermal expertise. Sephton Water Technologies, that is involved in the steam-driven desalination portion of the project, has implemented desalination at locations worldwide. The U.S. Bureau of Reclamation has expertise available. However, none of this expertise is intimately invested in a geothermal desalination project. In fact, the choice whether to implement this project as a restoration method (or whether to implement a restoration method at all) lies outside these experts and with a consortium of public and private parties. The cost of providing a restoration method at the Salton Sea, whether geothermal desalination or otherwise, would cost more than the available public funds earmarked for restoration. And, there are significant political factors that influence this project that are outside the scope of this report. Whether this project will be implemented will not be influenced significantly by involvement of the Energy Commission. There is a high level of expertise involved with this project, but because of significant political and financial factors that would influence the project, it is being given a rating of 2 out of 5.

Military Facility Heating: Sierra Army Depot

The basic analyses completed in this report indicate this project could be feasible for generic heat loads of five 5000 ft^2 buildings. However, the cost estimates included in this report did not include the cost of retrofitting those buildings to use geothermal resources. The likelihood the military will actually take on a geothermal space heating project is unknown. There are many unknowns associated with this project, including whether a suitable resource could be developed, the actual heating loads, types of heating systems, and types of buildings that would be included, and whether the facilities are used enough to warrant space heating systems. There was mention in the Geothermal Energy Resource Assessment on Military Lands Report that some portion of the Sierra Army Depot base was being considered for closure by the military[11]. This might negate any serious consideration for geothermal space heating. Even though this facility was found to be economically feasible for the generic load model used for evaluation, the many uncertainties associated with this project reduce its score. This project was given a rating of 2 out of 5.

Military Facility Heating: China Lake

The basic analyses completed in this report indicated this project was found not to be feasible for a generic load of five 5000 ft^2 buildings. If sufficiently large heating loads could be identified, it is possible that a space heating project at China Lake could be feasible. The likelihood the military will actually take on a geothermal space heating project is unknown. There are many unknowns associated with this project, including whether a suitable resource could be developed, the actual heating loads, types of heating systems, types of buildings that would be included, and whether the facilities are used enough to warrant space heating systems. Due to the lack of economic feasibility shown for the generic load model used for evaluation as well as the many uncertainties associated with this project, the project was rated a 1.5 out of 5.

Military Facility Heating: Twentynine Palms

The basic analysis completed in this report, indicated this project was found not to be feasible for a generic load of five 5000 ft^2 buildings. If large enough heating loads could be identified, it is possible that a space heating project at Twentynine Palms could be feasible. The likelihood the military will actually take on a geothermal space heating project is unknown. There are many unknowns associated with this project, including whether a suitable resource could be developed, the actual heating loads, types of heating systems, types of buildings that would be included are, and whether the facilities are used enough to warrant space heating systems. Due to the lack of economic feasibility shown for the generic load model used for evaluation, the many uncertainties associated with this project, and the fact that a project at Twentynine Palms would require even more base load than Sierra Army Depot or China Lake, the project was rated a 1 out of 5.

Military Facility Heating: Chocolate Mountains

The basic analysis completed for this report indicated this project was found not to be feasible for a generic load of five 5000 ft^2 buildings. If large enough heating loads could be identified, it is possible that a space heating project at Chocolate Mountains could be feasible. The likelihood of the military will actually take on a geothermal space heating project is unknown. There are many unknowns associated with this project, including whether a suitable resource could be developed, the actual heating loads, types of heating systems, types of buildings that would be included and whether the facilities are used enough to warrant space heating systems. Due to the lack of economic feasibility shown for the generic load model used for evaluation, the many uncertainties associated with this project, and the fact that a project at Chocolate Mountains would require even more base load than Sierra Army Depot or China Lake, the project was rated a 1 out of 5.

Conclusions

Several factors, developed through the research conducted for this report, are assumed to positively influence the likelihood of near-term development of a given geothermal direct-use project. These factors are:

- The availability of geothermal resources including methods to dispose of geothermal fluids
- Expertise in direct-use geothermal energy and the industry/business to which it is applied
- A desire to implement direct-use
- A “hero” who is personally invested that can push a project through many of the hurdles inherent with geothermal direct-use
- Past direct-use experience, especially with similar applications, at the site and by the parties involved
- Cost savings compared to alternative fuels provided that there are alternatives
- Ability to meet the economic requirements imposed on the project
- Ability to overcome political and bureaucratic barriers

These factors were used to rank the top 10 projects identified in this report. Those rankings are shown in Table 16 in the Review of Potential Geothermal Projects Section. Recommendations based upon those rankings are shown below.

Project Recommendations

Based on the evaluation we conducted, it is evident each of the highly ranked projects has unique attributes and challenges. We present below ways in which those challenges could be met and possible roles the California Energy Commission could assume in that process.

Mineral Extraction from Geothermal Brine at CalEnergy Company Facilities

This project is ranked first for likelihood of near-term development. The project is supported by CalEnergy Company with significant geothermal expertise. The company operates a commercial mineral extraction facility that produces zinc. CalEnergy Company has plans to expand its extraction operations to include manganese. Lithium and boron are considered options as well. These minerals are produced without the need for traditional mining and with very little impact on the environment compared to other methods of obtaining these minerals. The expansion to manganese may happen without further Energy Commission involvement; however, Commission support in the past has helped manganese extraction to become a viable near-term option. Continued involvement of the Commission could help foster the expansion of mineral extraction beyond zinc and manganese to include boron, lithium and others.

Aquaculture and Greenhouse Heating in Canby, CA

Though these projects are treated separately in this report, both are similarly dependant on the same factor; the development of a small geothermal electric-plant for the I'SOT community. The aquaculture project is ranked second for its industry expertise, direct-use "hero", and presence of an identified, definitive user.. The greenhouse project is ranked below aquaculture due to the lack of an identified user and the missing expertise in greenhouse growing. Both of these should not be difficult to find if the power plant waste water fluids from the geothermal-electric project become available. A recommendation to the Energy Commission is included. It states, even though it is outside the scope of this report, that further information on I'SOT plans for a small geothermal electric plant be pursued. If such a project were implemented, a good opportunity for direct-uses would result.

Direct-uses in the City of Paso Robles, CA

The current involvement of the Energy Commission in the City of Paso Robles new hot spring resource will result in benefit to the community. Certainly, proper disposal of effluent from the city center spring will be identified and implemented. However, it is suggested that more could result from the Commission's involvement beyond proper disposal of geothermal fluids. A good opportunity for direct use exists and that opportunity would result in one or more direct-use project(s) that would provide additional benefit to the community. Further participation by the Energy Commission will be dependant on the current, Commission-sponsored *City of Paso Robles Resource Assessment and Feasible Use Study.*

District Heating in Mammoth Lakes, CA

Mammoth Lakes could be a community that has nearly all its energy needs met by renewable sources. Just three miles away from the town of Mammoth is the MPLP Casa Diablo Power plant that generates its electricity from geothermal heat. A geothermal district heating system could provide geothermal space heating, water heating, and sidewalk, parking lot and road snow melting. If the Energy Commission decided to "advertise" geothermal direct-use, Mammoth Lakes would be the place to do it. Many tourists come to the area in the winter, driving up to Mammoth during snow fall. Finding roads that were clear of snow and ice, as well as condos, hotels and public buildings that have high-quality, inexpensive heating, all from geothermal sources, would be an important demonstration of the benefits to be derived from direct-use geothermal energy applications. Mammoth Lakes would be an even more attractive place than it is already. But, such an outcome would cost millions of dollars in capital costs that must be spent before the first user is ever connected, just to start with a system that only provides heating to certain buildings close to the center of town. To expand that system to provide heat community-wide and add snow-melting would be quite expensive.

However, there are ways to make district heating in Mammoth Lakes feasible. Even though the originally proposed idea of using waste hot water from the Casa Diablo power plant was found to be uneconomical, a system using a heat source closer to town could be feasible. As suggested by FVB Energy to the MCWD, this report suggests the Energy Commission find ways to assist the MCWD in determining if a resource close to town could be developed. If a geothermal resource near the community could be found, the outlook for district heating in Mammoth Lakes would improve.

Salton Sea Desalination Restoration

As the Salton Sea approaches 100 years since its accidental creation, the outlook for the Sea remaining as a marine habitat looks bleak. With a fairly constant inflow of salts and no current method of removing them, the future Sea will be too salty to support life. If nothing is done to reverse or stop this trend, the Salton Sea's role as a refuge for fish, birds and other wildlife will eventually end. This will have an impact on the people who live on or near the Sea as the Sea is a source of income, food and recreation. The political environment surrounding restoration of the Sea is intense and it is unknown what method of restoring the Sea will be chosen, or if the decision to restore the Sea will be made at all.

Although the Energy Commission cannot play a significant role now in geothermal desalination of the Salton Sea for restoration, it could become involved if geothermal desalination is used to restore the Sea. However, the Commission can play a role in the proposed smaller desalination facility that would operate off of waste steam at the CalEnergy Company power plant facilities. Such desalination could benefit the State not only by assisting Salton Sea's restoration, but also as a testing location for technologies that could be implemented in other areas of the State to provide fresh water as it becomes more scarce and valuable.

Military Facility Space Heating

This report found geothermal space heating to be feasible at the Sierra Army Depot facilities, but feasibility was based on several assumed factors. First, the heating loads used for assessment were generically equivalent to five 5000 ft^2 buildings. It is currently unknown whether an appropriate heat load exists at Sierra Army Depot. Also, there is not a definite resource, just an expectation for a resource developed from known geothermal resources in the surrounding area. The desire of the military to assume a space heating project at Sierra Army Depot is unknown as well. If these assumptions are found to be correct, then the Sierra Army Depot would have good potential for direct-use development. This report recommends that the Energy Commission pursue a relationship with the military to determine if Sierra Army Depot is truly a potential project. Also, a working relationship with the military could help further determine the feasibility of geothermal space heating at the other three bases discussed in this report.

Other Projects Not Included in the Detailed Assessment

Although not having as much potential for near-term development, the other direct-use projects identified in this report but not included in the detailed assessment should not be ignored. There is definite interest in constructing new geothermal spa facilities in the Desert Hot Springs area. The result of this interest could help sustain or refute the expectation that there is little opportunity for new geothermal spas in

California due to more stringent health regulations. The application of geothermal triple-uses should be of interest because of the opportunities for more efficient uses of geothermal resources. Algae farm pond heating is an extension of aquaculture that could benefit from the chemical characteristics common to geothermal fluids and the high levels of carbon dioxide would support algae growth as opposed to being a hindrance as it is for fish farming. There are geothermal resources in both Twentynine Palms and Huntington Beach that could be appropriate for direct-use applications. In total, these projects comparise much of what geothermal direct-uses could be in the future.

Other Recommendations

Reduce Bureaucratic Barriers to Geothermal Direct-use

Many of the geothermal direct-use operators interviewed for this report suggested permitting and government bureaucracy are barriers to new and existing projects. At least two operators in the Imperial Valley claimed that working with the Imperial Valley Planning Commission was difficult. According to those operators, the IVPC requires permit renewals for wells every four years. Added to the expense of this, the permit process is used as an “excuse” for inspections of facilities that include aspects well outside that of the geothermal systems.[77] [78]

Some other barriers were discovered during the literature search phase of this report. Obtaining documents in regards to permitting was found to be difficult. It could be a benefit to geothermal direct-use growth if information on implementing direct-use projects were more readily available. Many agencies can become involved in implementing a direct-use project. For example, during the implementation of their district heating project, I’SOT had to interact with the Department of Conservation - Division of Oil, Gas, & Geothermal, the regional water board, U.S. Fish & Wildlife, Department of Fish & Game, the Modoc County Planning Department, and the Environmental Health Department. For other projects, the list can be even longer. A consolidation of direct-use information and resources among these agencies, or even easier access to resources at each agency would be beneficial.

It is a responsibility of the government to protect our natural resources, geothermal fluids included. However, if ways to ease bureaucratic difficulties associated with geothermal direct-uses could be found, other natural resources could be protected through reducing pollution and the uses of fossil fuels. If used properly, geothermal energy is a renewable resource that could offset the use of other unsustainable energy sources.

Address Applications with High Potential but Low Implementation in California

This suggestion is directed at greenhouse heating, which was rated to have high potential for growth in California, but has very few actual project sites. Greenhouse heating is considered by some experts to be “the most stable direct-use application with respect to continued growth and good potential for expansion”. [6] According to lists of direct-use applications in California complied by the Geo-Heat Center, greenhouse heating has the fewest number of projects in California of all the major geothermal direct-use applications.[2] And, only one potential project was identified in this report. This report proposes that the Energy Commission undertake a study focusing specifically on geothermal greenhouse heating. This study could include identifying current greenhouse operators that are located in or near geothermal resource areas. Working with greenhouse operators, interest in geothermal heating as well as feasibility of such projects could be determined.

Appendix 1 Regional Statistics and Data

Table 17 Regional Statistics

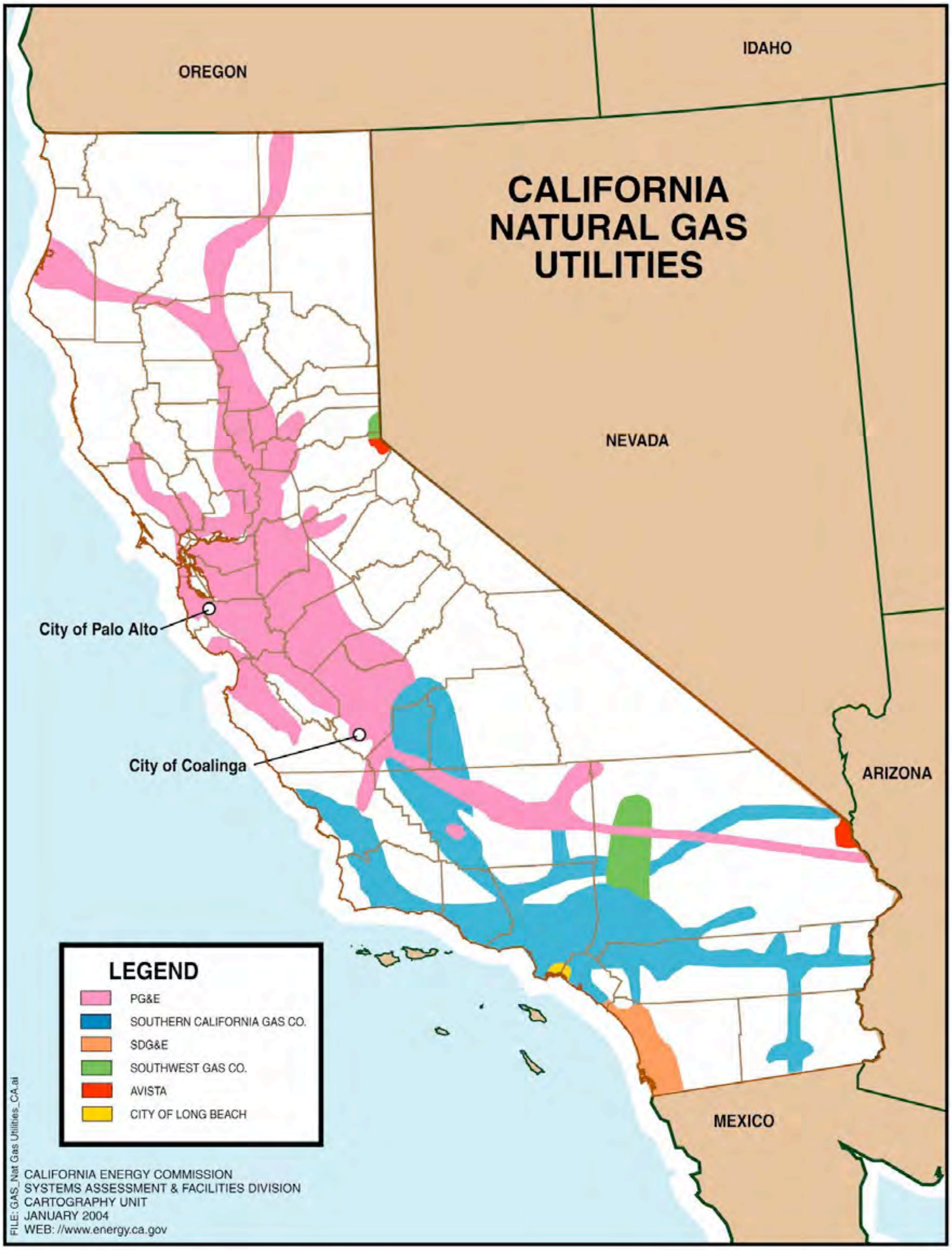
	Counties	Unemployment Rates[36]	Electricity Rates (cents/kWh)[45]	Persons / Square Mile[35]
Region A	Lake	8.1%	Provided by PG&E. Rates shown for small commercial customers	46.4
Geysers	Mendocino	5.4%		24.6
	average	*6.8%*	*19.48¢*	*35.5*
Region B	Alameda	6.4%		1957.4
S.F. Bay	Contra Costa	5.1%		1317.9
Area	Marin	3.5%		475.7
	Monterey	7.0%		120.9
	Napa	4.1%		164.9
	San Benito	8.5%		38.3
	San Mateo	4.6%		1574.7
	Santa Clara	7.6%		1303.6
	Santa Cruz	6.4%	Provided by PG&E. Rates shown for small commercial customers	574.1
	Sonoma	4.4%		291.0
	average	*5.8%*	*19.48¢*	*781.9*
Region C	Alpine	13.2%		1.6
Sierra	El Dorado	4.9%		91.4
Cascades	Kern	11.4%		81.3
	Lassen	4.1%		7.4
	Modoc	5.8%		2.4
	Mono	7.1%		4.2
	Nevada	4.2%		96.1
	Placer	4.6%		176.9
	Plumas	7.2%	Partially provided for by SCE, however the majority of the region is served by independent municipalities for which current weighted rates were not available. Rate shown is for SCE small commercial customers.	8.2
	Shasta	6.9%		43.1
	Sierra	6.6%		3.7
	Siskiyou	8.0%		7.0
	Tulare	14.2%		76.3
	average	*7.6%*	*18.69¢*	*46.1*
Region D	Imperial	22.1%	Providers are SCE and IID (Imperial Irrigation District). No weighted rates were available for IID. Rates shown are for SCE small comm. customers.	34.1
Imperial	Inyo	5.5%		1.8
Desert	Riverside	6.4%		214.4
	San Bernardino	5.6%		85.2
	average	*9.9%*	*18.69¢*	*83.9*
Region E	Los Angeles	6.8%		2344.2
South	Orange	3.7%		3605.6
Coast	San Diego	4.2%	Providers are SDG&E, SCE and PG&E. Rate shown is an average of rates for small commercial customers from the 3 providers	670.0
	San Luis Obispo	3.1%		74.7
	Santa Barbara	3.9%		145.9
	Ventura	5.6%		408.2
	average	*4.6%*	*18.42¢*	*1208.1*

Regional Statistics (Continued)

	Counties	Median Price of Home[79]	EASI ® Quality of Life Index [1] [80]	Manufacturing Jobs / 100 Sq Miles[81], [82]	Miles of Highway / 100 Sq Miles [82]
Region A	Lake	$122,600	128	28	72
Geysers	Mendocino	$170,200	156	142	43
	average	*$146,400*	*142*	*85*	*57*
Region B	Alameda	$303,100	159	13,459	473
S.F. Bay	Contra Costa	$267,800	159	3,311	440
Area	Marin	$514,600	177	1,090	214
	Monterey	$265,800	164	253	67
	Napa	$251,300	173	1,181	113
	San Benito	$284,000	138	142	42
	San Mateo	$469,200	170	7,755	451
	Santa Clara	$446,400	173	19,871	366
	Santa Cruz	$377,500	170	2,547	227
	Sonoma	$273,200	167	1,600	163
	average	*$345,290*	*165*	*5,121*	*255*
Region C	Alpine	$184,200	125	0	29
Sierra	El Dorado	$194,400	148	121	81
Cascades	Kern	$93,300	148	157	75
	Lassen	$106,700	126	9	27
	Modoc	$69,100	143	1	31
	Mono	$236,300	155	2	34
	Nevada	$205,700	158	320	94
	Placer	$213,900	168	738	126
	Plumas	$137,900	146	33	38
	Shasta	$120,800	155	113	53
	Sierra	$128,600	138	29	52
	Siskiyou	$100,300	144	19	30
	Tulare	$97,800	125	249	87
	average	*$145,308*	*145*	*138*	*58*
Region D	Imperial	$100,000	122	36	79
Imperial	Inyo	$161,000	173	3	17
Desert	Riverside	$146,500	153	674	103
	San Bernardino	$131,500	160	331	48
	average	*$134,750*	*152*	*261*	*61*
Region E	Los Angeles	$209,300	162	16,467	509
South	Orange	$270,000	174	29,013	916
Coast	San Diego	$227,200	169	2,986	185
	San Luis Obispo	$230,000	171	188	66
	Santa Barbara	$293,000	169	587	65
	Ventura	$248,700	168	1,765	138
	average	*$246,367*	*169*	*8,501*	*313*

[1] The EASI® Quality of Life Index is a combination measure developed from 29 different life quality variables. The index takes into account such factors as weather, crime, and availability of services. Weights are assigned based upon each variables importance to a high quality of life. The higher the number is, the better the quality of life. The U.S. average is 100. The index was created by asking businesses to choose factors they considered important in making a location more desirable to live in. Those factors are: EASI Weather Index (weight = 20) – includes average temperature, average annual heating, average annual cooling, percent sunshine, percent sky cover, number of clear days, range of daily temperatures, number of snow days, annual precipitation, and annual snowfall; EASI Total Crime Index (weight =-2); Earthquake Index (weight = 1); Culture Index (weight =3); Amusement Index (weight =3); Restaurants Index (weight =5); Medical Index (weight = 3); Religion Index (weight = 1); and Education Index (weight =2).

Figure 12 Natural Gas Utilities and Availability in California [83]



Appendix 2 Geothermal Resources in California

These following tables contain known geothermal resources in California. They are broken up geographically according to the regions shown in the section of this report labeled, Geothermal Resources. The information included is compatible with the California Department of Forestry's Geographical Information System (GIS) mapping software.[84]

Table 18 Geothermal Resources in Region A – Geysers [5]

Source Name	Type[2]	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Red Eye Spring	SP	39.3510	122.6705	24.0		8	14200
Elgin Mine (Spring)	SP	39.0570	122.4708	69.0		38	24699
Wilbur Hot Spring	SP	39.0387	122.4208	55.6		80	
"Sunedco/Bailey Min." 1	NLT	39.0333	122.4301	175.0	2711.6	197	
Empire Silver Mine	SP	39.0377	122.4255	38.0		1	14340
Jones Hot Spring (W)	SW	39.0338	122.4270	61.9			
Unnamed Springs	SP	39.0348	122.4265	61.0		15	
Blancks Hot Springs	SP	39.0312	122.4313	49.0		15	
Salt Spring	SP	39.4303	122.5363	24.0		20	22573
Crabtree Hot Springs	SP	39.2908	122.8217	41.0		76	5350
Unnamed Spring	SP	39.2000	122.7250	32.0		19	
Newman Springs	SP	39.1980	122.7143	33.0		94	
Newman Spring	SP	39.1980	122.7143	29.5		60	
Complexion Spring	SP	39.1703	122.5125	8.9			
Chalk Mt. Spring	SP	39.0722	122.5833	16.1			
Unnamed Spring	SP	39.0550	122.5933	21.0			
Hog Hollow Spring	SP	39.0233	122.5917	30.0		8	
Grizzly Spring	SP	39.0017	122.4983	19.4		6	
Sulphur Bank Wells	X	39.0038	122.6613	99.0	424.0		5700
Sulphur Bank Hot Springs	SP	39.0033	122.6633	70.0		1	4990
Unnamed Springs	SP	38.9858	122.7358	38.0		19	
Kettenhofen 1 Well	X	38.9492	122.7517	187.0	2385.0		
Big Soda Spring	SP	39.0080	122.7872	32.0		500	1116
Lake Co.,"Ag Park" 1	CLT	38.9357	122.7588	61.7	492.3		
Lake Co.,"Ag Park" 2	CLT	38.9339	122.7603	57.2	180.4		
Lake Co.,"Ag Park" 3	CLT	38.9320	122.7597	63.9	148.7		
Unnamed Well	WW	38.9783	122.8333	24.0		38	2337
Highland Springs	SP	38.9377	122.9078	28.0		15	2030

[2] Resource Types: Springs, SP; Well drilled to control spring flow, SW; Water Well, WW; Non-commercial low-temperature, NLT; Commercial low-temperature, CLT; Temperature gradient, TG; Injection Well, INJ; Petroleum well, OIL; Type not confirmed – most appear to be high-temperature exploration wells, X.

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
England Springs	SP	38.8967	122.8817	24.0		30	
Agricultural Park #3 Well	CLT	38.9250	122.7567	65.7		400	
Carlsbad Spring	SP	38.9180	122.7978	26.0		12	854
Sullivan 1 Well	X	38.8853	122.7917	82.0	1872.0		
Gordon Hot Spring	SP	38.8350	122.7308	34.6			
Seigler Hot Springs	SP	38.8760	122.6880	52.0		28	1565
Howard Hot Springs	SP	38.8583	122.6733	46.3		55	
Ettawa Springs	SP	38.8500	122.6900	21.7		2	
Pine Cone Spring	SP	38.8500	122.6900	27.0			
Sulfur Creek Spring	SP	38.8617	122.7567	21.0			
Spiers Spring	SP	38.8375	122.6517	24.2		15	
Anderson Springs	SP	38.7750	122.7333	49.4		2	
Harbin Springs	SP	38.7887	122.6563	48.0		30	390
Castle Rock Springs	SP	38.7708	122.7162	73.0		38	346
Baker Soda Spring	SP	38.8920	122.5320	21.3		3	
Jackson Valley Mud Sps.	SP	39.6578	123.5870	27.0		1	31900
Pinches Spring	SP	39.6962	123.4825	21.0		190	994
Muir Springs	SP	39.4288	123.3075	20.0			1820
Orrs Hot Springs	SP	39.2298	123.3649	40.0		114	436
Orr Hot Sps."Trilby Sp."	SP	39.2298	123.3649	28.0			445
Orr Hot Sps."Pool Sp."	SP	39.2298	123.3649	29.0			443
Orr Hot Sps. Well	SW	39.2298	123.3649	39.0	1.5		463
Vichy Springs	SP	39.1655	123.1562	29.0			
Cal-Dri Ice Co. Well	WW	39.0050	123.1083	W	241.0		6220
Point Arena Hot Sps.	SP	38.8772	123.5092	44.0		19	310
Hoods Hot Springs	SP	38.7958	123.1625	38.0		19	
The Geysers (Devils Kit.)	SP	38.8017	122.8067	100.0			6280
Unnamed Spring	SP	38.7767	122.7625	49.0		19	
Little Geysers	SP	38.7742	122.7478	71.0		30	
Stinking Springs	SP	40.2228	122.7495	38.0		57	1950

Table 19 Geothermal Resources in Region B – San Francisco Bay Area [5]

Source Name	Type[3]	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Crohare Spring	SP	37.6320	121.7620	21.0		8	659
Warm Springs	SP	37.5030	121.9067	27.0			339
Sulphur Spring	SP	37.9147	122.0420	24.0		8	1050
Unnamed Spring	SP	37.9292	121.9650	23.0			4830
Unnamed Well	WW	37.9375	121.9542	23.0	160.0	10	8210
Unnamed Spring	SP	37.8945	121.8737	21.0			10300
Byron Hot Springs	SW	37.8472	121.6305	51.0	75.0	600	14918
Mercy Hot Springs	SP	36.7033	120.8598	48.0			2209
Escarpado Spring	SP	36.6417	120.6833	24.0			26800
Coalinga Mineral Sps.	SP	36.1450	120.5562	31.0		4	414
Rocky Point Springs	SP	37.8858	122.6287	32.0		8	14000
San Luis Forebay Sp.	SP	37.0833	121.0417	21.0			1769
Iridat Spring	SP	36.7737	120.8990	23.0		76	381
Unnamed Spring	SP	36.7670	120.8995	27.0		38	489
Unnamed Spring	SP	36.6183	121.8445	38.0			
Unnamed Spring	SP	36.3312	121.8428	46.0		38	
Unnamed Spring	SP	36.2500	121.6833	W			
Slates Hot Springs	SP	36.1230	121.6353	47.0		95	245
Dolans Hot Springs	SP	36.0837	121.5863	37.0		114	168
Tassajara Hot Springs	SP	36.2337	121.5492	60.0		189	319
Paraiso Springs	SP	36.3313	121.3675	43.0		57	804
Sulfur Spring	SP	36.3313	121.3662	31.0		15	1010
Table Mountain (Spring)	SP	35.9083	120.3667	30.0			946
Unnamed Spring	SP	38.8333	122.3567	22.0		189	3190
Aetna Springs	SP	38.6522	122.4833	33.0		40	1970
Calistoga Pwr. Co. Well	X	38.5955	122.6003	138.0	350.0		
Calistoga Hot Springs	SW	38.5822	122.5728	78.0			713
Well 8N/6W-4F1 M	WW	38.5738	122.5322	81.0	63.0		690
Phillips Soda Springs	SP	38.5217	122.2608	24.0		38	
Napa Rock Soda Sps.	SP	38.5187	122.2597	26.0		84	1750
Well 8N/6W-25H2 M	WW	38.5175	122.4700	21.0			
White Sulfur Springs	SP	38.4905	122.4967	36.0		34	698
Well 7N/5W-3M1 M	WW	38.4850	122.4067	25.0	184.0		
Well 7N/5W-15A1 M	WW	38.4633	122.3942	21.0	93.0		
Well 7N/5W-14G1 M	WW	38.4592	122.3808	21.0	70.0		
Well 7N/5W-26D1 M	WW	38.4342	122.3908	27.0	5.0		
Well 7N/5W-26E1 M	WW	38.4308	122.3892	30.0	17.0		355
Napa Vichy Springs	SP	38.3388	122.2592	24.0		4	

[3] Resource Types: Springs, SP; Well drilled to control spring flow, SW; Water Well, WW; Non-commercial low-temperature, NLT; Commercial low-temperature, CLT; Temperature gradient, TG; Injection Well, INJ; Petroleum well, OIL; Type not confirmed – most appear to be high-temperature exploration wells, X.

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well 6N/4W-23J1 M	WW	38.3500	122.2650	29.0	184.0	184	
Unnamed Spring	SP	38.3208	122.2708	28.0			
Well 6N/4W-24M1 M	WW	38.3508	122.2600	24.0			
Wine Val. Inn,"Wilson" 1	CLT	38.5778	122.5774	49.0	101.5	114	
Calis. Sch. Dist.,"CHS" 1	CLT	38.5835	122.5792	W	106.7	284	
"Roman Spa" 1	CLT	38.5779	122.5775	71.1	64.0	95	
City Calistoga,"Calis" 1	INJ	38.5782	122.5794	84.4	173.5	276	
"Village Inn" 1	CLT	38.5779	122.5778	60.0	89.6	114	
Calis. Sch. Dist.,"CHS" 2	CLT	38.5827	122.5787	82.2	80.0	76	
Napa V.S.M.W.Co.,"Fox" 3	CLT	38.5818	122.5777	W	91.4		
"CDHS" 1	CLT	38.5776	122.5731	W			
Calistoga M.W.Co.,"CMW" 3	CLT	38.5855	122.5743	W	99.4		
Golden Haven Spa	WW	38.5858	122.5797	91.0	91.4	190	586
Golden Haven Spa	WW	38.5855	122.5792	31.0	27.0	19	262
Unnamed Well	WW	38.6005	122.6073	25.0	54.9	76	422
Unnamed Well	WW	38.5970	122.6007	135.0	57.9		518
Unnamed Well	WW	38.5962	122.6022	42.0	14.0	132	451
"Godward" 1	EST	38.5938	122.6015	81.0	65.2		492
Unnamed Well	WW	38.5945	122.6022	81.0	60.4		580
Unnamed Well	WW	38.5913	122.6053	20.0	25.9	68	354
Unnamed Well	WW	38.5893	122.6032	20.0	0.0		329
Unnamed Well	WW	38.6012	122.5978	37.0	121.9		567
Unnamed Well	WW	38.5965	122.5992	65.0	30.5		558
Unnamed Well	WW	38.5962	122.5990	116.0	58.8		599
Unnamed Well	WW	38.5960	122.5990	97.9	45.7		507
Unnamed Well	WW	38.5948	122.5967	47.0	0.0	19	594
Unnamed Well	WW	38.5922	122.5948	36.0	61.0		557
Unnamed Well	WW	38.5937	122.5945	23.0	9.4		151
Unnamed Well	WW	38.5917	122.5942	25.0	24.4		371
Unnamed Well	WW	38.5930	122.5945	21.0	9.1		300
Well 9N/7W-26 M	WW	38.5937	122.5950	21.0	12.2		412
Unnamed Well	WW	38.5980	122.5833	21.0	36.6	30	260
"Calvert" 1	WW	38.5965	122.5895	52.0	125.0		560
Unnamed Well	WW	38.5920	122.5935	40.0	61.0		578
Unnamed Well	WW	38.5885	122.5958	24.0	45.7		551
Unnamed Well	WW	38.5895	122.5972	22.0	22.9		319
Napa Co. Fairgrounds	WW	38.5843	122.5907	24.0	57.9	19	635
Unnamed Well	WW	38.5875	122.5842	49.0	51.8	76	648
"Turner" 1	WW	38.5893	122.5825	74.0	61.0	76	561
"Turner" 2	WW	38.5892	122.5827	20.0	24.4	19	292
Unnamed Well	WW	38.5900	122.5847	28.0	12.2		617
Well 9N/7W-36 M	WW	38.5907	122.5857	21.0	9.8	45	300
Unnamed Well	WW	38.5908	122.5853	35.0	36.6	38	428
Unnamed Well	WW	38.5928	122.5867	36.0	30.5		372
Unnamed Well	WW	38.5927	122.5828	44.0	0.0		506
Unnamed Well	WW	38.5758	122.5508	41.0	83.8		585

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Unnamed Well	WW	38.6008	122.5822	20.5	36.6	38	282
Unnamed Well	WW	38.5975	122.5813	25.0	33.5		318
Unnamed Well	WW	38.5825	122.5615	24.0	38.1		199
Unnamed Well	WW	38.5747	122.5592	26.0	121.9	11	338
Unnamed Well	WW	38.5860	122.5620	22.0	42.4		83
Unnamed Well	WW	38.5847	122.5630	20.0	30.5		97
Unnamed Well	WW	38.5913	122.5772	28.0			279
Unnamed Well	WW	38.5932	122.5957	33.0	61.0	114	564
Nance's Hot Sps. Well	WW	38.5815	122.5763	93.0	67.1		635
Calistoga Spa Cold Well 2	WW	38.5783	122.5760	22.0	25.9		570
Calistoga Spa Hot Well 2	WW	38.5787	122.5752	60.0	42.7		608
Calistoga Spa Main Well	WW	38.5783	122.5753	85.0	71.6		581
Pacheteau Well	SW	38.5822	122.5738	95.0	46.0	1968	610
Pacheteau's "Well 1"	WW	38.5823	122.5740	95.0	46.3	750	622
Pacheteau's "Well 2"	WW	38.5825	122.5738	96.0	50.0	750	619
Pacheteau's "Well 3"	WW	38.5823	122.5737	94.0	54.3		598
Dr. Wilkinson's Hot Sps.	WW	38.5803	122.5768	122.0	57.9		691
Unnamed Well	WW	38.5783	122.5742	25.0	56.4		136
Unnamed Well	WW	38.5782	122.5753	66.0	55.5		605
Unnamed Well	WW	38.5773	122.5728	34.0	51.8		698
Unnamed Well	WW	38.5772	122.5735	45.0			630
Roman Spa "Well 1"	WW	38.5792	122.5787	44.0	76.2		616
Roman Spa "Well 2"	WW	38.5792	122.5788	76.0	106.7		619
Unnamed Well	WW	38.5823	122.5758	60.0	21.3		467
Unnamed Well	WW	38.5810	122.5785	57.0	0.0		396
Hideway Hot Sps. Well 1	WW	38.5825	122.5785	51.0	36.6		368
Hideway Hot Sps. Well 2	WW	38.5822	122.5793	28.0	10.7		656
Napa Val. Sps. Bottle Co.	WW	38.5833	122.5757	104.0	63.1	49	633
Unnamed Well	WW	38.5772	122.5742	30.0	0.0		713
Unnamed Well	WW	38.5775	122.5738	57.0	62.5		712
Mt. View Hotel	WW	38.5792	122.5780	85.0	70.1		580
Unnamed Well	WW	38.5750	122.5778	35.0	61.0	265	477
Unnamed Well	WW	38.5827	122.5872	41.0	57.0	64	744
Unnamed Well	WW	38.5850	122.5558	43.0	82.3	114	334
Unnamed Well	WW	38.5747	122.5513	20.0	61.0		112
Unnamed Well	WW	38.5842	122.5548	27.0	74.7		266
Unnamed Well	WW	38.5840	122.5552	25.0	38.1	132	193
Unnamed Well	WW	38.5665	122.5647	23.0	64.6	36	176
Unnamed Well	WW	38.5725	122.5692	27.0	73.2		501
Unnamed Well	WW	38.5853	122.6010	21.0	0.0		372
Unnamed Well	WW	38.5815	122.5962	20.0	64.6	95	443
Unnamed Well	WW	38.5852	122.5998	20.0	16.8		442
Unnamed Well	WW	38.5843	122.5545	30.0	77.7	261	236
Unnamed Well	WW	38.5840	122.5543	28.0	70.1	61	104
Unnamed Well	WW	38.5858	122.6040	20.0	91.4	45	352
Unnamed Well	WW	38.5833	122.6067	35.0	131.1	95	320

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Unnamed Well	WW	38.5567	122.5237	20.0	54.9		152
Unnamed Well	WW	38.5563	122.5222	20.0	48.8		198
Unnamed Well	WW	38.5707	122.5142	20.0	42.7		516
Unnamed Well	WW	38.5760	122.5167	21.0	61.0		341
Unnamed Well	WW	38.5763	122.5187	40.0	106.7	38	277
Unnamed Well	WW	38.5938	122.6065	22.0	146.3	132	316
Unnamed Well	WW	38.5917	122.6110	21.0	56.7	151	303
Unnamed Well	WW	38.5777	122.5257	30.0	48.8		299
Unnamed Well	WW	38.5882	122.5803	85.0	64.9	64	644
Unnamed Well	WW	38.5878	122.5795	55.0	86.9	26	471
Unnamed Well	WW	38.5988	122.6075	20.0	46.0		430
Unnamed Well	WW	38.5970	122.6158	20.0	30.5		296
Unnamed Well	WW	38.5948	122.6145	20.0	33.5	95	424
Unnamed Well	WW	38.5943	122.6147	20.0	30.5	57	384
Unnamed Well	WW	38.5937	122.6128	20.0	36.6	76	389
Unnamed Well	WW	38.5503	122.5375	22.0	73.2		148
Unnamed Well	WW	38.5620	122.5382	20.0	79.2		215
Unnamed Well	WW	38.5887	122.5968	33.0	64.0		578
Unnamed Well	WW	38.5925	122.5920	27.0	45.7		552
Unnamed Well	WW	38.5650	122.5355	23.0	54.9		169
Unnamed Well	WW	38.5760	122.5295	55.0	54.9	13	592
San Benito Mnr. Well	WW	36.8155	121.3528	24.0	87.0	76	2610
Sulfur Springs	SP	36.2945	120.9853	23.0		189	16081
White Sulphur Spring	SP	37.3973	121.7970	29.0		19	2130
Gilroy Hot Spring	SP	37.1092	121.4778	41.0		15	1290
Sargent Estate Warm Sp.	SP	36.9405	121.5640	25.0		3	840
Maplethorpe Well	WW	36.9833	121.9417	23.0			573
Lone Tree Mnr. Spring	SP	37.5732	121.4452	22.0			400
Unnamed Spring	SP	37.5685	121.4462	23.0		38	1080
Tolenas Springs	SP	38.3102	122.0532	20.0		1	18165
Vallejo White Sulphur Sp.	SP	38.1248	122.1882	20.0		263	
Unnamed Spring	SP	38.1012	122.1688	23.0		64	788
Skaggs Springs	SP	38.6938	123.0257	55.0		15	2500
Mark West Springs	SP	38.5488	122.7200	31.0		1	327
Unnamed Spring	SP	38.3885	122.5670	23.0		76	260
Morton's Warm Sps. Well	SW	38.3943	122.5498	31.0	54.9		488
Unnamed Spring	SP	38.3567	122.5087	21.0		38	370
Agua Caliente Sps. Well	WW	38.3220	122.4877	35.0	91.4	1022	426
Fetters Hot Springs Well	WW	38.3220	122.4877	29.0	291.0	291	286
Agua C. School,"SV Geo" 1	CLT	38.3220	122.4872	W	183.0		
Boyes Hot Sps. Well	SW	38.3145	122.4864	43.0	107.0		842
Boyes Hot Sps. "No.1"	SW	38.3143	122.4863	28.0			
Boyes Hot Sps. "No.2"	SW	38.3147	122.4866	50.6	140.8		1140
Sonoma Mission Inn,"SV" 1	CLT	38.3138	122.4823	53.1	396.3	757	1287
Well 8N/8W-34M M	WW	38.4933	122.7382	22.9	153.3		357
Well 7N/8W-2E M	WW	38.4845	122.7197	21.8	112.5		156

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well 8N/8W-35L M	WW	38.4950	122.7127	22.8	142.6		
Well 8N/8W-35P M	WW	38.4899	122.7133	20.1	155.4		
Well 7N/8W-12D M	WW	38.4709	122.7022	21.0	9.1		
Well 7N/8W-12E M	WW	38.4687	122.7024	24.0	70.1		282
Well 7N/8W-12N M	WW	38.4612	122.7036	29.4	153.6		316
Well 7N/8W-12N M	WW	38.4604	122.7014	22.8	36.6		
Unnamed Spring	SP	38.4602	122.7017	22.4			
Well 7N/8W-24A4 M	WW	38.4428	122.6862	30.0	305.0		362
Well 7N/8W-24H M	WW	38.4416	122.6860	29.0	366.0		
Unnamed Spring	SP	38.4520	122.6483	22.0			
Well 7N/7W-16G M	WW	38.4549	122.6352	31.7	39.0		310
Well 7N/7W-32G9 M	WW	38.4099	122.6524	30.6	125.0		
Well 7N/7W-32L M	WW	38.4091	122.6564	20.0	86.0		
Well 6N/7W-5A M	WW	38.4010	122.6491	30.0			426
Well 6N/7W-9A M	WW	38.3851	122.6308	22.0	177.4		446
Well 6N/8W-1Q M	WW	38.3908	122.6914	W	84.0		
Well 7N/7W-25G M	WW	38.4239	122.5798	23.8	166.0		180
Well 7N/6W-33D M	WW	38.4143	122.5366	W			
Well 7N/6W-32A M	WW	38.4121	122.5387	W			
Unnamed Well	WW	38.3997	122.5667	20.0			281
McEwan Ranch Spring	SP	38.3883	122.5685	23.0			265
Nunn's Iron Spring	SP	38.4084	122.4859	20.0			80
Sonoma State Hosp. Well	WW	38.3563	122.5086	20.0	7.0		
Unnamed Well	WW	38.3467	122.5010	21.0	76.0		381
Sonoma State Hosp. No. 3	WW	38.3445	122.5193	37.5	436.0		
Unnamed Well	WW	38.3333	122.4970	22.0	76.0		273
Unnamed Well	WW	38.3297	122.4900	22.0	79.0		300
Well 6N/6W-35G M	WW	38.3236	122.4900	26.0	57.3		
Well 6N/6W-35E M	WW	38.3227	122.4959	28.1	207.3		
Unnamed Well	WW	38.3042	122.4968	21.0	52.0		280
Well 5N/6W-12D M	WW	38.2978	122.4775	31.0	213.0		220
Unnamed Well	WW	38.2980	122.4733	30.0	226.0	492	193
Unnamed Well	WW	38.2947	122.4585	21.0	70.0		211
Unnamed Well	WW	38.2958	122.4570	21.0	73.2	191	214
Unnamed Well	WW	38.2992	122.4568	24.0	61.0	492	132
Unnamed Well	WW	38.2983	122.4502	28.0	67.1	530	409
Well 5N/5W-7G M	WW	38.2964	122.4498	28.0	137.0		
Well 5N/5W-7G M	WW	38.2946	122.4496	25.0	46.0		
Unnamed Well	WW	38.2960	122.4547	23.0	152.0	1800	206
Unnamed Well	WW	38.2942	122.4567	29.0	107.0		211
Unnamed Spring	SP	38.3248	122.4049	28.4			
Unnamed Well	WW	38.2823	122.4635	20.0	53.0		296
Well 5N/5W-17L M	WW	38.2817	122.4356	29.3	305.0		
Unnamed Well	WW	38.2670	122.4992	20.0	156.0		233
Well 5N/5W-31A1 M	WW	38.2426	122.4454	20.0	124.0		585
Well 5N/5W-28R1 M	WW	38.2460	122.4092	20.0	85.0		615

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Unnamed Well	WW	38.2537	122.3883	28.0	213.0		291
Well 4N/5W-7C M	WW	38.2126	122.4547	28.0	61.0		
Unnamed Well	WW	38.2163	122.3728	20.0	74.0		385
Well 5N/6W-25P2 M	WW	38.2461	122.4728	38.0	195.0		405
Salt Grass Springs	SP	37.4312	121.3083	23.0		4	2925

Table 20 Geothermal Resources in Region C – Sierra Cascades [5]

Source Name	Type[4]	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Grovers Hot Springs	SP	38.6980	119.8450	60.0		400	1236
Unnamed Spring	SP	38.7728	119.7130	65.0		473	
Valley Springs	SP	38.1952	120.8225	24.0		4	2530
Wentworth Springs	SP	39.0130	120.3380	24.0		6	
Meyers Warm Spring	SP	38.8500	120.0250	24.0		15	114
Fish Creek Hot Sps.	SP	37.5320	119.0245	43.0		19	
Unnamed Spring	SP	37.4125	119.1392	35.0			
Mono Hot Springs	SP	37.3267	119.0167	43.0		200	1347
Blaney Meadows Hot Sps.	SP	37.2337	118.8813	43.0		150	824
Keough Hot Springs	SP	37.2538	118.3765	58.0		2000	453
Unnamed Springs	SP	37.2675	118.2722	29.0			
Meadow Hot Spring	SP	35.7290	118.4112	41.0		15	240
Meadow Hot Spring No.6	SP	35.7290	118.4150	20.0		3	
Scovern Hot Springs	SP	35.6205	118.4730	54.0		415	
Miracle Hot Springs	SP	35.5762	118.5330	50.0		49	204
Delonegha Hot Springs	SP	35.5733	118.6128	43.0		30	300
Unnamed Spring	SP	35.5353	118.6495	W			
Democrat Hot Springs	SP	35.5288	118.6668	39.0		57	278
Yates Hot Springs	SP	35.4330	118.4788	38.0		30	
Warm Spring	SP	35.1475	118.7830	W			
Well 28S/27E-7C2 M	WW	35.5133	119.1083	29.0			132
Well 26S/40E-30K2 M	WW	35.6433	117.7132	30.0	244.0	5000	277
Placer Claim Springs	SP	35.5777	118.5493	40.0		10	479
Bare Ranch Spring	SP	41.1667	120.0333	32.0		19	254
Warm Spring	SP	41.1625	120.4038	21.0		21	
Kellog Hot Spring	SP	41.1275	121.0250	90.0		15	880
Bassett Hot Springs	SP	41.1450	121.1108	79.0		200	735
Unnamed Springs	SP	41.0133	121.2725	W			
Roosevelt Pool Well	X	40.4092	120.6622	38.0			233
Church of L.D.S. Well	WW	40.4063	120.6600	49.0	172.0	800	558
Wirth Well No. 1	WW	40.4072	120.6540	49.0	42.0		
N. State Growers Well	WW	40.4047	120.6563	61.0	190.0		660
N. No. 1 Well	WW	40.4087	120.6587	63.0			
Lassen Lumber & Box 2 (W)	X	40.4013	120.6475	37.0			
Eagle Lake Lumber Well	WW	40.4033	120.6317	27.0			446
Unnamed Well	WW	40.4133	120.6583	53.0			
"Davis" 2	NLT	40.4110	120.6606	76.7	140.2	1514	

[4] Resource Types: Springs, SP; Well drilled to control spring flow, SW; Water Well, WW; Non-commercial low-temperature, NLT; Commercial low-temperature, CLT; Temperature gradient, TG; Injection Well, INJ; Petroleum well, OIL; Type not confirmed – most appear to be high-temperature exploration wells, X.

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
"Susan" 1	CLT	40.4125	120.6651	78.9	283.5	1325	
Tsuji Nursery "TNI" 2 (W)	CLT	40.4070	120.6579	68.3	184.5	2305	
"Johnston" 1	CLT	40.4030	120.4863	79.4	434.1	3956	
"Johnston" 2	CLT	40.4027	120.4896	63.3	443.9		
Well 30N/13E-31R1 M	WW	40.4083	120.5500	26.0			
Sellicks Springs	SP	40.5667	120.3250	22.0		3939	
Tipton Springs	SP	40.5800	120.2650	21.0		3496	
Well 29N/15E-16G1 M	WW	40.3733	120.2933	27.0			
Wendel Hot Springs	SP	40.3558	120.2555	96.0		1200	1040
Magma Power Co. Wendel 1	X	40.3583	120.2542	79.0	192.0		
Southern Pacific RR Well	WW	40.3420	120.2208	28.0	93.0	300	279
Magma Power Amedee 1,2	X	40.3000	120.1947	107.0	334.0	227	830
Amedee Hot Springs	SP	40.3042	120.1958	95.0		6840	860
Well 28N/17E-20J1 M	WW	40.2650	120.0750	27.0			
High Rock Spring	SP	40.2467	120.0068	30.0		1984	
Unnamed Spring	SP	39.9800	120.0638	42.0		577	
Zamboni Hot Springs	SP	39.9195	120.0233	40.0		95	197
Reds Meadow Hot Sps.	SP	37.6183	119.0733	46.0		50	923
Warm Spring	SP	41.9587	120.9428	W			
Pothole Spring	SP	41.8252	120.9153	26.0		38	
Weidner Well	WW	41.9478	120.3175	47.0	150.0	3000	437
Fort Bidwell Hot Sp. Well	X	41.8617	120.1592	45.0		400	458
Fort Bidwell Geo. Well	NLT	41.8617	120.1578	46.0	155.0	1512	551
Well 46N/16E-31R1 M	WW	41.8078	120.1708	28.0	13.0		256
Well 45N/16E-17M1 M	WW	41.7667	120.1812	53.0	24.0		1060
Well 44N/16E-6E2 M	WW	41.7142	120.1975	25.0	137.0		431
Magma Energy Wells	X	41.6718	120.2167	160.0	1508.0	1370	1200
Lake City Mud Volcano Sp.	SP	41.6680	120.2092	97.0			1210
Hutchen's Well	WW	41.5833	120.1700	48.0	124.0		
Unnamed Well	WW	41.5817	120.1792	69.0	194.0	570	
Robison Well	WW	41.5658	120.1917	50.0	77.0	605	
Leonards Hot Sps. (West)	SP	41.5987	120.0913	41.0		200	1200
Seyferth Hot Springs	SP	41.6158	120.1033	85.0		500	1110
Leonards Hot Sps. (East)	SP	41.6015	120.0850	62.0		150	1180
Surprise Val. Mnr. Well	WW	41.5333	120.0773	86.0		100	763
Unnamed Spring	SP	41.5297	120.0870	98.0		600	936
Benmac Hot Springs	SP	41.5305	120.0822	98.0		700	949
Menlo Baths Hot Springs	SP	41.2658	120.0820	56.0		95	248
Unnamed Spring	SP	41.2083	120.0542	43.0			220
Unnamed Spring	SP	41.2217	120.0667	41.0		175	202
Unnamed Spring	SP	41.1917	120.3833	77.0		12	1220
Unnamed Spring	SP	41.1967	120.4708	W			
Unnamed Spring	SP	41.2532	120.5208	24.0			
New Williams R. Well	WW	41.2683	120.5250	29.0	62.0	150	
Van Loan Well	WW	41.2617	120.5303	44.0	30.0	175	186
Unnamed Spring	SP	41.3600	120.7233	27.0		380	

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Unnamed Spring	SP	41.4667	120.5250	22.0		4	
CA. Pines Lodge	NLT	41.4090	120.6856	38.0	238.0	946	
Modoc Sch. Dist.,"AL" 1	CLT	41.4917	120.5405	86.1	896.6	303	2230
Alturas Elem. Sch.,"AL" 2	CLT	41.4901	120.5553	83.3	594.5		1537
Unnamed Spring	SP	41.5417	120.5667	27.0		38	
Essex Springs	SP	41.4928	120.6992	33.0		500	
SX Ranch Spring	SP	41.4850	120.7635	26.0		19	198
SX Ranch Well	WW	41.5117	120.7775	24.0		190	267
Kelly Hot Spring	SP	41.4540	120.8347	92.0		1250	899
Kelly Hot Sp. Ranch Well	WW	41.4517	120.8350	116.0	1035.0		
"Canby School" 1	TG	41.4566	120.8531	37.0	206.0	1514	258
Little Hot Spring	SP	41.2305	121.4033	73.5		300	913
Weidner Well	WW	41.9478	120.3175	47.0			402
Unnamed Spring	SP	38.6267	119.5042	W			365
Sierra E. Mobile Pk. Well	WW	38.5250	119.4750	35.0			191
Unnamed Well	WW	38.5333	119.4667	W	97.9		
Fales Hot Springs	SP	38.3505	119.4003	61.0		1000	1651
Magma Power Co. Well	X	38.3500	119.4000	38.0	126.0		
Buckeye Hot Springs	SP	38.2392	119.3250	60.0		400	1430
Travertine Hot Spring	SP	38.2463	119.2042	82.0		50	4324
The Hot Springs	SP	38.2242	119.2145	40.0		100	4394
Magma Power Co. Well	X	38.2250	119.2125	51.0	300.0		
Warm Spring	SP	38.2022	119.1207	25.0		2	13
Dechambeau Well	SW	38.0500	119.0817	66.0	287.0	20	960
Unnamed Spring	SP	38.0542	119.0633	54.0			1594
State PRC 4572.1 Well	X	38.0245	119.0832	58.0	743.0		
Warm Springs	SP	38.0330	118.9043	31.0		76	1934
Unnamed Springs	SP	37.9958	119.0233	86.0		250	26342
State PRC 4397.1 Well	X	37.9393	119.0302	54.0	1220.0		
Unnamed Spring	SP	37.9400	119.0192	42.0		4	1914
Unnamed Spring (Tunnel)	SP	37.8358	119.0158	36.0			
Unnamed Fumaroles	SP	37.6192	119.0278	W			
Casa Diablo Hot Springs	SP	37.6458	118.9150	82.0			
Magma Power Co. Wells	X	37.6458	118.9167	177.0	324.0		1555
Mammoth Lakes,"MLGRAP" 1	CLT	37.6511	118.9796	77.0	468.1		
Mammoth Lakes,"MLGRAP" 2	CLT	37.6406	118.9642	74.0	490.7		
Mammoth Lakes,"Ohwell" 1	CLT	37.6359	118.9888	79.4	664.0		
Hot Bubbling Pool	SP	37.6470	118.8600	68.0			1261
Little Hot Creek Sps.	SP	37.6900	118.8400	82.0		717	1115
Hot Creek Springs	SP	37.6645	118.8275	88.0		15000	1110
Unnamed Spring	SP	37.7080	118.8133	38.0			
Big Alkali Lake Sp.	SP	37.6700	118.7815	57.0		75	1261
Whitmore Hot Springs	SP	37.6308	118.8117	37.0		1560	510
Unnamed Spring	SP	37.6433	118.7575	41.0		150	1137
Unnamed Spring	SP	37.6367	118.7242	28.0			270
Unnamed Springs	SP	37.7192	118.7375	24.0			

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Benton Hot Springs	SP	37.8008	118.5300	57.0		800	269
Benton Indian Well	WW	37.7963	118.5233	30.0	73.0	75	305
Bertrand Ranch Springs	SP	35.8917	118.4917	21.0		378	
Brockway Hot Springs	SP	39.2273	120.0133	55.0		600	371
Unnamed Spring	SP	40.4425	121.4125	28.0		30	
Devil's Kitchen	SP	40.4413	121.4333	95.0			1402
Terminal Geyser	SP	40.4213	121.3767	96.0		30	
Drake Hot Springs	SP	40.4425	121.4025	66.0		76	510
Boiling Springs Lake	SP	40.4357	121.3967	88.0			
Terminal Geyser Well	X	40.4208	121.3767	129.0	387.0		
Indian Valley Hot Sps.	SP	40.1413	120.9337	41.0		30	
Indian Val. Hosp., GRN-1	NLT	40.1441	120.9445	47.2	165.5	946	598
Plumas Sch. Dist., GHS-1	NLT	40.1397	120.9446	34.4	198.0	38	567
Warm Sps. at Twain	SP	40.0187	121.0358	38.0		19	1743
White Sulfur Springs	SP	39.7283	120.5475	27.0		95	222
Marble Hot Wells	WW	39.7565	120.3583	73.0	109.0	95	1185
Well 22N/14E-25H1 M	WW	39.7310	120.3533	38.0	7.0	40	1170
Well 22N/15E-17C3 M	WW	39.7650	120.3242	29.0	290.0		195
Well 23N/15E-36J2 M	WW	39.8008	120.2408	26.0	190.0	4	200
Well 22N/15E-23C1 M	WW	39.7500	120.2700	28.0	232.0		190
Well 22N/15E-28L1 M	WW	39.7292	120.3055	32.0			170
W. Hagge Well No.1	WW	39.7217	120.3217	40.0		3	1270
Well 22N/15E-32F1 M	WW	39.7158	120.3242	94.0	335.0	50	1570
Well 22N/15E-32R1 M	WW	39.7092	120.3167	52.0	274.0		
Well 22N/15E-33M1 M	WW	39.7153	120.3100	32.0			
Hunt Hot Springs	SP	41.0338	121.9300	56.0		27	804
Unnamed Well	WW	41.0162	121.9067	29.0	149.0		318
Big Bend Hot Springs	SP	41.0225	121.9195	82.0		340	1930
Indian Sps. Sch. Well	NLT	41.0165	121.9075	28.0	138.0	333	436
Indian Sps. Sch.,"ISS" 1	NLT	41.0205	121.9065	50.0	250.0	114	260
Well 31N/4W-7A1 M	WW	40.5625	122.3542	31.0			
Unnamed Springs	SP	40.4567	121.5417	66.0		11	
Tophet Hot Springs	SP	40.4503	121.5338	93.0		19	
Bumpass Hell	SP	40.4575	121.5000	93.0		400	1420
Well 21N/15E-5D1 M	WW	39.7058	120.3308	44.0	185.0		920
Well 21N/15E-5E1 M	WW	39.7025	120.3317	34.0	122.0		
Well 21N/15E-5E2 M	WW	39.7017	120.3317	51.0	122.0	8	1160
Well 21N/15E-5P1 M	WW	39.6942	120.3275	29.0	122.0		120
Well 21N/15E-6Q1 M	WW	39.6950	120.3383	27.0	229.0		
Well 21N/15E-6Q3 M	WW	39.6950	120.3400	27.0	77.0		265
Well 21N/15E-4L1 M	WW	39.6988	120.3062	30.0			330
Campbell Hot Springs	SP	39.5782	120.3537	42.0		284	334
Sierra Co.,"SCGP" 1	CLT	39.6822	120.3188	38.3	398.2	1249	
Sulphur Springs	SP	41.6595	123.3182	29.0		8	270
Bogus Soda Springs	SP	41.9187	122.3707	21.0		113	10622
Klamath Hot Springs	SP	41.9712	122.2017	69.0		95	1940

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well 48N/1W-28F1 M	WW	41.9767	121.9878	28.0	193.0		120
Unnamed Well	WW	41.9370	121.8505	30.0			
Unnamed Fumarole	SP	41.6058	121.5237	88.0			
Unnamed Spring	SP	41.4088	122.1948	84.0		4	1550
Growler Hot Spring	SP	40.3942	121.5078	95.0		38	4540
Morgan Hot Springs	SP	40.3837	121.5133	96.0		323	4064
Tuscan Springs	SP	40.2408	122.1100	29.0		3	21574
Kern Hot Spring	SP	36.4780	118.4047	43.0		15	910
Jordan Hot Spring	SP	36.2292	118.3017	43.0		285	3280
Soda Springs	SP	36.2105	118.1758	38.0		8	
Soda Spring	SP	36.1298	118.8158	22.0		6	2030
Ward Spring	SP	36.1167	118.7758	21.0		4	154
California Hot Springs	SP	35.8795	118.6770	45.0		500	193

Table 21 Geothermal Resources in Region D – Imperial Desert [5]

Source Name	Type[5]	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Fish Springs Well	WW	33.4180	116.0400	46.0			11080
Fish Springs	SP	33.4070	116.0347	28.0		57	1900
Well 9S/9E-23M1 S	WW	33.3742	116.0133	27.0			6200
Ballard's Truckhaven	WW	33.2972	115.9762	38.0	392.0	45	3750
Well 10S/9E-35N1 S	WW	33.2520	116.0108	59.0	604.0		2210
Well 10S/9E-36P1 S	WW	33.2513	115.9872	33.0	195.0		5798
Holly Corp. Hot Mnr. Well	WW	33.2475	116.0008	58.0			2256
Jacobs No.3 Well	X	33.1167	116.0195	39.0	366.0		1169
Jacobs No.2 Well	X	33.1170	116.0097	31.0	204.0		1650
Landmark Corp. Well	X	33.0638	116.0308	35.0	361.0		281
Well 14S/11E-32R1 S	WW	32.9030	115.8480	28.0	300.0		1870
C.L. Smith Well	WW	32.7167	115.9630	29.0	46.0		878
J. Greene Well	WW	32.7833	115.9478	29.0	32.0		15243
Dollinger Well	WW	32.7763	115.9405	30.0	91.0		9345
Miller's Serv. Sta. Well	WW	32.7292	116.0167	34.0	163.0		334
H.D. Currey Well	WW	32.7388	116.0047	29.0	107.0		923
Davis Spring (Well)	SW	32.6945	116.0250	28.0			394
Texaco Station Well	WW	32.7305	115.9937	33.0	167.0		300
W. Simpson Well	WW	32.6897	115.9247	29.0	92.0		455
Unnamed Well	WW	33.4250	115.6917	77.0			4060
Hot Mineral Spa Well	WW	33.4258	115.6855	88.0	99.0	900	2810
Bashford's Hot Mnr. (W)	WW	33.4237	115.6808	62.0	75.0		3270
"Bashford" 1	CLT	33.4179	115.6799	74.4	510.7	57	
Fountain Of Youth Well	WW	33.4033	115.6617	60.0	192.0		4670
Fountain of Youth,"Spa" 2	CLT	33.3991	115.6626	W	198.0		
Well 9S/13E-20E1 S	WW	33.3788	115.6437	31.0			4077
"Niland" 1	CLT	33.4179	115.6799	W	146.4		
"Niland" 2	CLT	33.4160	115.6782	W	146.3		
"Niland" 3	CLT	33.4176	115.6788	W	146.0		
"Imperial" 1	CLT	33.4182	115.6743	61.5	480.0		
"Imperial" 2	CLT	33.4164	115.6811	65.0	148.5	1703	
"Imperial" 3	CLT	33.4205	115.6786	H	163.0		
Unnamed Mud Volcano	SP	33.3450	115.5875	W			
Unnamed Mud Volcano	SP	33.3450	115.5700	W			
Unnamed Mud Volcano	SP	33.3233	115.5700	W			
Unnamed Mud Volcano	SP	33.3233	115.5875	W			
Unnamed Mud Volcano	SP	33.3117	115.6067	W			

[5] Resource Types: Springs, SP; Well drilled to control spring flow, SW; Water Well, WW; Non-commercial low-temperature, NLT; Commercial low-temperature, CLT; Temperature gradient, TG; Injection Well, INJ; Petroleum well, OIL; Type not confirmed – most appear to be high-temperature exploration wells, X.

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Unnamed Mud Volcano	SP	33.3117	115.5875	W			
Unnamed Mud Volcano	SP	33.2850	115.5700	W			
Unnamed Mud Volcano	SP	33.2850	115.5883	W			
Well 11S/14E-2A1 S	WW	33.2442	115.4772	44.0	251.0		1810
Fish Producers, "Ray" 1	CLT	33.2293	115.4646	W	270.0		
Unnamed Mud Pot	SP	33.2197	115.5803	38.0			
J. Massion Well	WW	33.2197	115.5787	40.0			23271
Earth Energy Hudson 1	X	33.2122	115.5695	40.0	1871.0		
Unnamed Mud Pots	SP	33.2125	115.5958	38.0			
Well 11S/13E-22H1 S	WW	33.1983	115.5970	28.0	46.0		1600
IID 3 - Imp. Therm. Pr.	X	33.2053	115.5883	105.0	517.0		34700
Earth Energy Rvr Ranch 1	X	33.2025	115.5780	345.0	2470.0		
Unnamed Mud Pot	SP	33.2008	115.5772	38.0			16300
O'Neill Geothermal Inc.	X	33.2005	115.5872	310.0	1441.0		334987
IID 1 - Imp. Therm. Pr.	X	33.2020	115.5917	316.0	1595.0		257800
IID 2 - Imp. Therm. Pr.	X	33.1967	115.5983	348.0	1776.0	3300	259000
Elmore 1 Well	X	33.1830	115.6122	360.0	2169.0	2400	318000
Magmamax 3 Magma Power	X	33.1687	115.6228	321.0	940.0		
Magmamax 2 Magma Power	X	33.1687	115.6292	278.0	1329.0		
Magmamax 1 Magma Power	X	33.1625	115.6187	265.0	690.0		203406
Magma Power, Woolsey 1	X	33.1625	115.6145	171.0	713.0		98600
Sinclair 4	X	33.1487	115.6213	164.0	1373.0		285000
Sinclair 3	X	33.1470	115.6075	168.0	1439.0	4500	153836
Well 13S/14E-9R1 S	WW	33.0287	115.5233	138.0	2545.0		
C. Bowles Well	WW	33.1262	115.4778	41.0	280.0		1185
Well 12S/15E-3A1 S	WW	33.1617	115.3887	31.0	263.0		2148
Well 12S/15E-26J1 S	WW	33.0962	115.3722	33.0	105.0		1450
Well 12S/15E-27R1 S	WW	33.0897	115.3888	34.0	131.0		1710
Well 13S/15E-5D1 S	WW	33.0667	115.4478	36.0	264.0	40	2330
Well 13S/15E-3N1 S	WW	33.0442	115.4162	41.0	271.0		1620
Well 13S/15E-3Q1 S	WW	33.0450	115.4047	40.0	268.0		1320
Well 13S/15E-1B1 S	WW	33.0612	115.3703	55.0	332.0		3220
Well 13S/16E-6A1 S	WW	33.0603	115.3522	32.0			1250
Well 12S/16E-31N1 S	WW	33.0750	115.3487	39.0	282.0	20	3350
Well 13S/16E-6J1 S	WW	33.0495	115.3492	33.0	189.0		1730
Well 13S/16E-18F1 S	WW	33.0222	115.3583	28.0	188.0		1127
Well 13S/16E-6P1 S	WW	33.0438	115.3583	32.0	91.0	20	1830
Well 13S/16E-6N1 S	WW	33.0438	115.3622	38.0			1610
Well 13S/15E-1Q1 S	WW	33.0467	115.3703	29.0	122.0		1343
Meyer-Dickerman Well	WW	33.0305	115.3703	37.0			1400
Dickerman-Butters Well	WW	33.0233	115.3663	52.0			1888
Well 13S/15E-16Q1 S	WW	33.0158	115.4238	39.0	232.0	40	1610
Well 13S/15E-24E1 S	WW	33.0083	115.3805	39.0			1200
Well 13S/15E-24N1 S	WW	33.0013	115.3813	43.0	213.0	60	1610
Well 13S/15E-23Q1 S	WW	33.0013	115.3887	56.0	396.0	160	3020
T. Shank Well	WW	32.9825	115.4488	44.0	307.0		2640

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
N. Fifield Well	WW	32.9678	115.4488	51.0	393.0		3810
Magnolia School Well	WW	32.9825	115.4220	51.0	425.0	140	3410
Well 13S/15E-33K1 S	WW	32.9745	115.4242	33.0	319.0		5710
M. Phegley Well	WW	32.9750	115.4150	44.0	291.0	40	1960
Fifield-Hoepner Well	WW	32.9747	115.4067	22.0	319.0		1055
Orita Feed Lot Well	WW	32.9750	115.4012	43.0	274.0		1460
B. Emanuelli Well	WW	32.9825	115.3362	41.0			531
Well 13S/16E-28R1 S	WW	32.9867	115.3158	36.0			1680
Mamer-Shank Well	WW	32.9533	115.4320	31.0	244.0		3170
J. Birger Well	WW	32.9450	115.4317	31.0	118.0	20	3400
Moiola Feed Lot Well	WW	32.9533	115.3972	42.0	199.0	28	1820
Gisler-Bowman Well	WW	32.9380	115.4058	48.0	355.0	239	2120
Mendiburu Lot Well	WW	32.9433	115.3788	52.0	378.0		2970
F. Borchard Well	WW	32.9580	115.3195	38.0	139.0	48	1390
F. Borchard Well	WW	32.9595	115.3208	37.0	140.0		1370
Well 14S/16E-11H1 S	WW	32.9508	115.2837	35.0	87.0		1310
Well 14S/16E-16B1 S	WW	32.9387	115.3197	32.0	137.0		1030
Well 14S/16E-15K1 S	WW	32.9313	115.3197	25.0	122.0	4	1020
Well 14S/16E-21D1 S	WW	32.9245	115.3283	36.0	137.0		1080
Well 14S/16E-21B1 S	WW	32.9245	115.3197	33.0		20	1270
Well 14S/16E-22D1 S	WW	32.9245	115.3113	42.0	216.0	20	2580
Coons Well	WW	32.9025	115.3055	31.0			637
Well 14S/16E-19N1 S	WW	32.9153	115.3650	50.0	346.0		1310
J. Birger No. 1 Well	WW	32.9170	115.3975	39.0	230.0	20	1740
J. Birger No. 2 Well	WW	32.9097	115.4045	32.0	123.0	16	1920
H. Foster Well	WW	32.9025	115.4233	31.0	116.0		1399
Jenson Well	WW	32.8953	115.4063	30.0	109.0	120	2140
Gaddis Well	WW	32.8838	115.4042	36.0	187.0	60	2150
Well 15S/15E-1H1 S	WW	32.8770	115.3705	38.0	177.0		1240
Well 15S/16E-7F1 S	WW	32.8630	115.3583	27.0	158.0		1120
Hooke Well	WW	32.8578	115.3530	36.0	212.0	12	1610
Well 15S/15E-12H1 S	WW	32.8622	115.3705	38.0			1024
Unnammed Well	WW	32.8617	115.3750	38.0			1020
C. Allen Well	WW	32.8478	115.4095	40.0	263.0	40	1750
Well 15S/15E-13N1 S	WW	32.8397	115.3792	36.0	244.0		978
Well 15S/15E-9N1 S	WW	32.8575	115.4333	34.0	183.0		4990
Well 15S/15E-10G1 S	WW	32.8622	115.4062	32.0	140.0	108	2220
Well 15S/15E-9E1 S	WW	32.8655	115.4317	33.0	189.0		2600
Unnamed Well	WW	32.8500	115.4583	38.0			
Well 15S/14E-13E1 S	WW	32.8480	115.4820	35.0	36.0		9110
Magma Ener. Bonanza 1	X	32.8317	115.5088	H	1531.0		
Unnamed Well	WW	32.8583	115.5667	30.0			10520
Magma Ener. Fed-Rite 1	X	32.6867	115.6562	H	1640.0		
Magma Ener. Holtz 2	X	32.7153	115.5578	159.0	1490.0		12800
Magma Ener. Holtz 1	X	32.7153	115.5425	168.0	1531.0		11800
Chevron, Nowlin Partner	X	32.7153	115.5263	H	1533.0		14080

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well 15S/15E-26B1 S	WW	32.8187	115.3892	40.0	396.0		1760
Well 15S/15E-25D1 S	WW	32.8225	115.3825	37.0			1313
Well 15S/15E-25F1 S	WW	32.8200	115.3792	40.0			1280
Well 15S/15E-25B1 S	WW	32.8217	115.3670	44.0			2140
Well 15S/16E-18Q1 S	WW	32.8405	115.3525	36.0	134.0		
Well 15S/15E-36D1 S	WW	32.8095	115.3803	29.0		12	1270
Well 15S/15E-35A1 S	WW	32.8100	115.3847	45.0	355.0	115	2330
Spanish Trails Park	WW	32.8155	115.3638	43.0	473.0		1725
A. Fusi Jr. Well	WW	32.8113	115.3538	40.0	305.0		1600
Well 15S/16E-29Q2 S	WW	32.8108	115.3372	37.0			1020
R. Garewal Well	WW	32.8430	115.3087	32.0	245.0		1460
Well 15S/16E-22L1 S	WW	32.8325	115.3062	35.0	229.0	12	1830
Well 15S/16E-23F1 S	WW	32.8337	115.2908	34.0	171.0	100	1300
Well 15S/16E-36E1 S	WW	32.8037	115.2753	38.0	192.0		787
Magma Ener. Sharp 1	X	32.7962	115.2863	126.0	1851.0		
C. Ansiel Well	WW	32.7888	115.3230	36.0	287.0		2080
Mesa 6-2 U.S.B.R.	X	32.7858	115.2555	186.0	1804.0	900	2377
Mesa 6-1 U.S.B.R.	X	32.7862	115.2488	204.0	2426.0	1500	26889
UC 6-1S1 Well	X	32.7862	115.2488	33.0	46.0		435
Mesa 5-1 U.S.B.R.	X	32.7942	115.2305	170.0	1829.0		2394
U.C. Riverside 127 Well	X	32.7662	115.2362	83.0	429.0		3260
Linden Gravel Well	WW	32.7653	115.2700	49.0	247.0		1864
Schneider-Guthrie Well	WW	32.7717	115.2762	42.0	251.0		478
Watton Camp Well	WW	32.7658	115.2838	43.0	344.0		1680
Well 16S/16E-15B1 S	WW	32.7658	115.3028	37.0	305.0	16	1420
Lechuga Store Well	WW	32.7561	115.3367	40.0			1210
Well 16S/16E-33D1 S	WW	32.7225	115.3280	31.0	244.0		1550
L. Bornt Well	WW	32.6925	115.3350	35.0	218.0		1460
Magma Ener. Sharp 2	X	32.7155	115.2978	H	1977.0		
Smith Brothers Well	WW	32.9987	115.0738	71.0	207.0		1300
Erma Mine Well	WW	32.9983	114.9817	30.0	213.0		
Gold Rock Ranch Well	WW	33.8683	114.9117	37.0	210.0		
U.S.B.R. No. 115 Well	X	32.8020	115.0153	100.0	107.0		
Grapevine Spring	SP	37.0268	117.3833	37.0		115	634
Upper Warm Springs	SP	36.8320	117.7370	50.0			897
Palm Spring	SP	36.8130	117.7653	50.0			876
Lower Burro Warm Spring	SP	36.8058	117.7717	43.0			850
Little Hunter Canyon Sps.	SP	36.6978	117.8480	27.0		568	539
Unnamed Spring	SP	36.4955	117.8928	30.0		57	1502
Dirty Socks Hot Sps. Well	SW	36.3295	117.9487	34.0	183.0		7813
Devils Kitchen Fumarole	SP	36.0347	117.7987	97.0			2260
Coso Hot Springs Well	SP	36.0462	117.7692	97.0			5345
Unnamed Fumarole	SP	36.0337	117.8330	97.0			
Unnamed Spring	SP	35.9400	117.9025	27.0		1	960
Bainter Spring	SP	35.8428	117.3817	24.0		1	250
Well 24S/43E-22M1 M	WW	35.8297	117.3295	32.0	91.0		10980

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well 24S/43E-9P1 M	WW	35.8558	117.3405	58.0	183.0		53450
Warm Sulfur Springs	SP	36.1225	117.2150	27.0		4	
Warm Spring	SP	35.9667	116.9312	W			381
Tecopa Hot Springs	SP	35.8718	116.2312	42.0		757	1705
Resting Spring	SP	35.8775	116.1560	27.0		980	
Well 21N/7E-28P1 S	WW	35.8858	116.2333	48.0	107.0	40000	2156
Unnamed Spring	SP	35.8883	116.2578	W			
Chappo Spring	SP	35.9478	116.1883	27.0		38	
Shoshone Spring	SP	35.9800	116.2730	32.0			965
Travertine Springs	SP	36.4408	116.8292	32.0			601
Nevares Springs	SP	36.5122	116.7900	40.0		1325	652
Keane Wonder Hot Spring	SP	36.6762	116.9258	34.0		113	3001
Well 26S/39E-19Q1 M	WW	35.6525	117.8197	31.0	112.0		455
Well 26S/39E-24P1 M	WW	35.6528	117.7313	34.0	252.0		210
Well 26S/40E-22P1 M	WW	35.6533	117.6633	32.0	253.0		1000
Well 27S/40E-7G1 M	WW	35.6033	117.7117	30.0	125.0		1740
Agua Caliente Spring	SP	33.8250	116.5447	41.0			207
Unnamed Well	WW	33.9083	116.3717	49.0			
Unnamed Well	WW	33.8992	116.3633	44.0	131.0		800
Well 5S/6E-24N2 S	WW	33.7177	116.3165	28.0	109.0		
Well 7S/9E-18M1 S	WW	33.5617	116.0925	32.0			170
Well 8S/8E-10B1 S	WW	33.4958	116.1375	33.0			200
Well 8S/8E-13Q1 S	WW	33.4700	116.1033	32.0			170
Well 8S/9E-29Q1 S	WW	33.4412	116.0692	43.0			435
Well 8S/9E-29R1 S	WW	33.4408	116.0642	39.0			470
Dos Palmas Spring	SP	33.5108	115.8262	29.0		1136	1350
Aqua Farms,"Aqua" 1	CLT	33.5088	115.8315	W	305.0		
Aqua Farms."Aqua" 2	CLT	33.5074	115.8303	W	152.0		
Aqua Farms,"Aqua" 3	CLT	33.5074	115.8327	W	64.6		
Hunter's Spring Wells	WW	33.4883	115.7908	32.0			2000
Canyon Spring	SP	33.5452	115.6533	36.0			21340
Kaiser North Well	X	33.9417	115.4167	29.0			90
Thurman Ragsdale Well	WW	33.8250	115.4250	40.0	183.0		88
Stanley Ragsdale Well	WW	33.7125	115.4042	33.0	183.0		846
Sunland Oil Well	X	33.7058	115.4400	30.0	198.0		66
Lazy C Trailer Park Well	WW	33.7408	115.3700	30.0			79
Cal Trans Well	WW	33.7133	115.4082	32.0			1217
S.D. Trailer Park Well	WW	33.7167	115.3958	34.0	152.0		763
Morrison Well	WW	33.7490	115.3560	36.0		3780	373
Desert Ctr. Airport Well	WW	33.7533	115.3317	30.0	69.0		1000
Corn Spring	SP	33.6250	115.3247	22.0			810
McCoy Spring	SP	33.7330	114.9067	28.0			1440
Wiley Well	WW	33.6092	114.9017	48.0	518.0		1036
L.C. Winters Well	WW	33.6958	114.6767	31.0	116.0		1290
Well 6S/22E-9P1 S	WW	33.6625	114.6858	32.0	84.0		1670
Well 6S/22E-20A1 S	WW	33.6458	114.6942	31.0	84.0		840

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Riverside Co. Airport (W)	WW	33.6117	114.7083	31.0			212
Mesa Verde Well	WW	33.6167	114.7333	31.0	110.0		466
Nicholls Warm Sps. Well	SW	33.6033	114.7278	33.0	195.0		3010
Blythe-Mesa Verde Well	SW	33.6020	114.7180	30.0		491	1613
Basha # 3 Well	X	33.5683	115.7458	45.0	417.0		4540
Bill Passey Well	WW	33.6042	115.6923	31.0	171.0		1520
Basha # 1 Well	X	33.6258	114.6800	31.0		8422	910
E. Weeks Well	WW	33.6467	114.6625	33.0	178.0		750
E. Fortner Well	WW	33.6958	114.6583	31.0	123.0		1330
Blythe-Julian Well	WW	33.6948	114.6533	29.0		1890	1537
Lucky 7 Well	WW	33.9258	116.4408	93.0	101.0		
"Pratt" 1	NLT	33.9248	116.4369	W	77.0		
"Mohnsen" 1	NLT	33.9397	116.4650	30.6	113.4		
"Sky Valley" No. 1	NLT	33.9242	116.4127	61.7	158.5		
"Segal" 1	NLT	33.9363	116.4670	W	100.6	57	
"Linda Vista Lodge" 1	CLT	33.9480	116.4879	70.0	91.0		
King Spa Well	WW	33.4375	115.6900	79.0	106.0		1280
New Pilger Hot Mnr. Well	WW	33.4275	115.6867	82.0			2850
"Leiss" No. 1	CLT	33.4300	115.6899	63.0	164.6		
"Leiss" No. 2	CLT	33.4286	115.6897	63.0	33.5		
M.H. Morris Well	X	35.7750	117.3600	30.0			91800
Saratoga Spring	SP	35.6818	116.4217	28.0		475	3040
Sheep Creek Spring	SP	35.5892	116.3583	23.0			720
Magma Power Co. Well	X	35.3843	117.5362	96.0	236.0		
Paradise Spring	SP	35.1433	116.8137	40.0		104	512
Soda Station Sps.	SP	35.1422	116.1050	24.0		189	1990
Newberry Spring	SP	34.8263	116.6763	25.0		1192	290
Flamingo Well	WW	34.9555	114.8388	39.0			345
Unnamed Well	WW	34.8417	114.9750	33.0	317.0		320
Roy Lye Well No.1	WW	34.0995	114.4500	27.0		2646	2876
Well 1S/24E-10N1 S	WW	34.0950	114.4533	30.0	101.0		1420
Roy Lye Well No.2	WW	34.0907	114.4628	30.0		1323	743
Well 1S/24E-16B1 S	WW	34.0917	114.4600	42.0	69.0		1070
Well 2N/7E-3B1 S	WW	34.2937	116.2367	27.0			180
Well 1N/8E-2N1 S	WW	34.1942	116.1217	53.0			730
Jewell Well	WW	34.1798	116.0648	32.0	36.0	500	1104
Zuncich Well	WW	34.1718	116.0987	39.0	120.0	800	752
Well 1N/9E-29F1 S	WW	34.1450	116.0633	48.0			450
Well 1N/9E-14C1 S	WW	34.1783	116.0117	63.0			1240
Well 1N/5E-12D1 S	WW	34.1917	116.4192	42.0	145.0		190
Pan Hot Spring	SW	34.2717	116.8375	32.0			337
Unnamed Spring	SP	34.3410	117.1690	38.0		19	
Unnamed Spring	SP	34.3392	117.1760	42.0		19	
Circ T Trailer Park Well	WW	33.1492	116.1825	37.0	95.0		99
M.A. Smith Well	WW	33.1562	116.1680	31.0	91.0		326
E. Robinson Well	WW	33.1445	116.1342	37.0	64.0		286

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
A. Toner Well	WW	33.1450	116.1183	32.0	61.0		443
A. Williams Well	WW	33.1258	116.1300	36.0	45.0		184
Cornish Well	WW	33.1058	116.1300	32.0	70.0		143
De Anza Trail Inn Well	WW	33.1247	116.1308	36.0	100.0	264	633
C. Peterson Well	WW	33.1387	116.1555	32.0	87.0		167
Ironwood Motel Well	WW	33.1495	116.1820	37.0	102.0		101

Table 22 Geothermal Resources in Region E – South Coast [5]

Source Name	Type[6]	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Mize Spring	SP	35.4833	119.9167	23.0			3060
Carneros Spring	SP	35.4388	119.8463	32.0		189	476
Unnamed Spring	SP	35.3667	119.7213	34.0			2830
Warm Springs	SP	34.6072	118.5622	33.0		76	1210
Well 6N/12W-13N1 S	WW	34.6025	118.1083	27.0			193
Well 4N/16W-1Q1 S	WW	34.4542	118.5125	28.0			875
Seminole Hot Sps. Well	SW	34.1075	118.7908	46.0	915.0	15	565
Well 1N/16W-14K1 S	WW	34.1667	118.5250	56.0			1690
El Encino Springs	SP	34.1592	118.4988	26.0		17	1160
Bimini Hot Sps. Well	SW	34.0692	118.2907	40.0	534.0	380	1780
Well 2S/14W-14C2 S	WW	34.0183	118.3167	27.0			430
Well 1S/9W-1F1 S	WW	34.1150	117.7800	36.0			380
Well 2S/11W-8N1 S	WW	34.0050	118.0617	29.0			435
Alvarado Hot Sps. Well	SW	33.9758	117.8863	44.0	1525.0	142	7740
Well 3S/11W-14H4 S	WW	33.9125	117.9958	34.0			413
Well 4S/13W-27N1 S	WW	33.7917	118.2350	28.0			285
Well 5S/13W-6D1 S	WW	33.7750	118.2833	31.0			1275
Unnamed Spring	SP	33.8017	118.4000	25.0			
Whites Point Hot Sps.	SP	33.7150	118.3183	46.0			
La Vida Mnr. Sp. Well	SW	33.9350	117.7917	43.0		76	4360
Well 3S/9W-22C2 S	WW	33.9025	117.8125	73.0			592
Seguro No.1 Well	X	33.6895	118.0062	218.0	2777.0		
Obrien Porter No.2 Well	X	33.6842	117.9983	H			
McCasden Well	X	33.6688	118.0137	H			
Beloil Davenport Well	X	33.6750	117.9958	H			
Fairview Hot Sp. Well	SW	33.6733	117.9183	36.0		57	
Well 5S/9W-34Q1 S	WW	33.6883	117.8035	30.0			259
Well 7S/8W-16Q1 S	WW	33.5567	117.7167	28.0			1156
Unnamed Spring	SP	33.5137	117.6043	35.0			440
San Juan Hot Springs	SP	33.5890	117.5003	49.0		57	319
Glen Ivy Hot Sp. Well	SW	33.7562	117.4945	55.0			300
Well 3S/7W-11F1 S	WW	33.9250	117.5875	48.0	280.0		
Well 3S/3W-2L1 S	WW	33.9388	117.1650	27.0			280
Well 3S/2W-7P1 S	WW	33.9200	117.1333	40.0			
Highland Springs	SP	33.9695	116.9417	44.0			161
Eden Hot Springs	SP	33.8967	117.0542	43.0		114	260
Unnamed Spring	SP	33.8658	117.0993	W			

[6] Resource Types: Springs, SP; Well drilled to control spring flow, SW; Water Well, WW; Non-commercial low-temperature, NLT; Commercial low-temperature, CLT; Temperature gradient, TG; Injection Well, INJ; Petroleum well, OIL; Type not confirmed – most appear to be high-temperature exploration wells, X.

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Lakeview Hot Springs	SP	33.8378	117.1445	38.0			
Gilman Hot Springs	SP	33.8350	116.9867	47.0		76	588
Soboba Hot Springs	SP	33.8008	116.9267	40.0		40	185
Well 5S/1E-5M2 S	WW	33.7633	116.9067	49.0			100
Well 5S/1W-16C1 S	WW	33.7417	116.9917	39.0			1320
Wrenden Hot Springs	SP	33.6692	117.3275	48.0			300
Elsinore Hot Springs	SW	33.6695	117.3287	45.0		8	254
Lake Elsinore,"GW" 1	CLT	33.6691	117.3268	W	150.0		
Lake Elsinore,"GW" 2	CLT	33.6706	117.3251	W	150.0		
Lake Elsinore,"GW" 3	CLT	33.6683	117.3281	29.5	183.0		
Well 6S/2W-10D1 S	WW	33.6705	117.0823	37.0	34.0		750
Unnamed Well	WW	33.6708	117.0637	37.0			600
Well 5S/1W-32Q1 S	WW	33.6858	117.0022	28.0	27.0		2110
Well 6S/1W-4J2 S	WW	33.6783	116.9795	43.0	40.0		330
Well 6S/2W-10E1 S	WW	33.6667	117.0828	49.0	6.0		2160
Well 6S/2W-15D1 S	WW	33.6555	117.0825	25.0	5.0		410
Well 6S/4W-34J2 S	WW	33.6045	117.2753	40.0	43.0		270
Well 6S/4W-35D1 S	WW	33.6122	117.2740	43.0	60.0		330
Temecula Hot Springs	SP	33.5533	117.1675	47.0			715
Well 8S/3W-7D3 S	WW	33.5033	117.2392	29.0			675
Murrieta Hot Springs	SP	33.5588	117.1572	54.0			673
Well 7S/2W-3N1 S	WW	33.5838	117.0828	40.0			965
Well 7S/2W-2P2 S	WW	33.5862	117.0573	37.0			790
Unnamed Spring	SP	33.5417	116.7417	W			
Tylers Bath (Spring)	SP	34.2305	117.4838	33.0			
Waterman Hot Spring	SP	34.1892	117.2710	51.0		19	1150
Waterman Hot Springs	SP	34.1892	117.2710	78.0		19	
Waterman Hot Springs (W)	SW	34.1887	117.2710	81.0		150	729
Arrowhead Hot Springs	SP	34.1870	117.2630	90.0		190	950
Arrowhead Hot Springs (W)	SW	34.1870	117.2647	84.0		189	644
"Granite Hot Spring"	SP	34.1868	117.2645	81.0		38	
"Penyugal Hot Spring"	SP	34.1872	117.2633	87.0			
"Palm Hot Spring"	SP	34.1870	117.2612	82.0			
"Mud Bath Well"	SW	34.1870	117.2612	84.0			700
"Hot Well"	WW	34.1897	117.2610	29.0			
Unnamed Springs	SP	34.1220	117.0787	32.0		11	
Harlem Hot Springs Well	SW	34.1225	117.2247	49.0			350
Harlem Hot Sps.(R 385)	SW	34.1230	117.2247	46.0	91.0		
Harlem Hot Springs Well	SW	34.1230	117.2247	49.0			
Well (State # E-53h)	SW	34.1227	117.2245	54.0	59.0		
Well (State # E-50h)	SW	34.1227	117.2252	H	88.0		
Well 1N/3W-32N3 S	WW	34.1233	117.2250	54.0	59.0		
Well 1N/3W-33M1 S	WW	34.1267	117.2050	51.0	152.0		
Urbita Hot Sps. Well	SW	34.0867	117.2958	41.0		760	320
Urbita Springs Well	WW	34.0875	117.2972	W	112.0	757	
Urbita Hot Sps. Wells	WW	34.0868	117.2958	41.0			

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well 1S/4W-15L3 S	WW	34.0833	117.2875	41.0			240
Patton Hospital #14	WW	34.1413	117.2203	25.0	152.0		288
Patton Hospital #10	WW	34.1372	117.2242	22.0	128.0		
Patton Hospital #11	WW	34.1343	117.2207	40.0	134.0		359
Well (R 375)	WW	34.1355	117.2372	22.0	140.0		
Well 1N/3W-31L4 S	WW	34.1283	117.2343	H	30.0		
Patton Hospital #9	WW	34.1268	117.2343	36.0	140.0		460
Well (R 361)	WW	34.1232	117.2280	30.0	21.0		
Well (State # E-50m)	WW	34.1222	117.2287	52.0	61.0		
Base Line Laundry Well	WW	34.1225	117.2322	28.0			352
Well 1S/3W-6C3 S	WW	34.1208	117.2350	43.0	42.0		
Well (R 327)	WW	34.1208	117.2442	27.0	56.0		
Well (R 328)	WW	34.1203	117.2433	24.0	52.0		
Well (R 329)	WW	34.1187	117.2427	22.0	70.0		
Well (R 330)	WW	34.1172	117.2427	20.0	45.7		
E.S.B.C.W.D. No.6	WW	34.1218	117.2492	41.0	212.0		
"Bone Yard Well"	WW	34.1187	117.2487	49.5	216.0		
"Palm Well #1"	WW	34.1252	117.2073	31.0	152.0		420
Well 1S/3W-4C1 S	WW	34.1210	117.1998	23.0	134.0		
Dunkirk #1	WW	34.1172	117.1990	21.0	124.0		372
Dunkirk #2	WW	34.1170	117.1993	21.0	119.0		389
Well 1S/4W-8Q3 S	WW	34.0942	117.3178	W	137.0		
Well 1S/4W-8R2 S	WW	34.0948	117.3167	W	133.0		
Well (R 297)	WW	34.0925	117.3123	32.0	137.5		
Colton #12	WW	34.0927	117.3125	31.0	275.6		255
Well 1S/4W-9J1 S	WW	34.0978	117.3002	22.0	154.9		
Well 1S/4W-10E1 S	WW	34.0997	117.2928	32.0	77.0		
Well (State # E-92y)	WW	34.0992	117.2918	29.0	241.0		
Well (State # E-29a)	WW	34.1022	117.2907	27.0	324.7		
"Mill & D St. Well"	WW	34.0925	117.2913	21.0	169.8		269
"Mill & D" 2	CLT	34.0927	117.2914	58.0	284.0		
Well 1S/4W-16G5 S	WW	34.0885	117.3033	H			
Well (234)	WW	34.0823	117.3068	29.0	48.2		
De Sienna Hot Sp. Well	WW	34.0817	117.3067	30.0	166.8		
Well 1S/4W-16L3 S	WW	34.0823	117.3048	42.0	182.9		
Well (23)	WW	34.0840	117.2982	37.0	36.9		
Well (19)	WW	34.0823	117.2978	22.0	68.6		
Well 1S/4W-16J2 S	WW	34.0825	117.2973	41.0	53.4		
Meeks & Daly Coburn Well	WW	34.0823	117.2988	26.0	213.0		288
Meeks & Daly #69	WW	34.0815	117.2982	32.0	244.0		
Well 1S/4W-16Q1 S	WW	34.0802	117.3012	W	27.7		
Meeks & Daly New E	WW	34.0817	117.2942	23.0	274.0		
Meeks & Daly Old E	WW	34.0817	117.2938	W	184.0		
Meeks & Daly #51	WW	34.0797	117.2942	25.0	262.2		
Well 1S/4W-21A1 S	WW	34.0752	117.2962	W	89.0		
Well (State # E-39v)	WW	34.1052	117.2775	23.0	349.4		

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Well (465)	WW	34.1102	117.2682	20.0	165.9		
Well (315)	WW	34.1043	117.2563	20.0	207.9		
Meeks & Daly #66	WW	34.0862	117.2890	56.0	297.3		336
"Byrne Well"	WW	34.0775	117.2868	30.0	335.4		
Meeks & Daly #59	WW	34.0818	117.2865	43.0	350.6		272
Well (State # E-98e)	WW	34.0767	117.2837	29.0	362.2		
Well (State # E-130h)	WW	34.0763	117.2812	22.0	226.8		
Well 1S/4W-22A1 S	WW	34.0762	117.2805	29.0	196.0		212
"Thorn # 12"	WW	34.0770	117.2837	24.0	199.4		
Well (252)	WW	34.0803	117.2717	20.0	25.3		
Well 1S/4W-23C2 S	WW	34.0762	117.2715	W	363.4		
Well (121)	WW	34.0738	117.2640	21.0	59.8		
Well (122)	WW	34.0745	117.2638	21.0	57.9		
Well (123)	WW	34.0752	117.2637	21.0	43.3		
Well (124)	WW	34.0767	117.2623	20.0	46.3		
Well (126)	WW	34.0782	117.2587	20.0	55.2		
Well (127)	WW	34.0798	117.2575	21.0	129.9		
Well (128)	WW	34.0807	117.2570	21.0	143.9		
Well (112)	WW	34.0802	117.2523	44.0	195.7		
Well (106)	WW	34.0740	117.2565	23.0	157.6		
Well (104)	WW	34.0737	117.2522	21.0	154.3		
Well (017)	WW	34.0692	117.2925	23.0	24.7		
Well (053)	WW	34.0695	117.2895	22.0	20.7		
Well (018)	WW	34.0685	117.2922	23.0	28.0		
Well 1S/4W-22G2 S	WW	34.0722	117.2852	W			
Well 1S/4W-22H3 S	WW	34.0728	117.2788	51.0	259.8		
Well 1S/4W-22H4 S	WW	34.0717	117.2782	43.0	294.2		
Well 1S/4W-27A8 S	WW	34.0627	117.2783	W	264.6		
Well (008)	WW	34.0598	117.2788	20.0	38.1		
Well (120)	WW	34.0618	117.2700	20.0	239.0		
Well (119)	WW	34.0607	117.2702	23.0	98.5		
Well (118)	WW	34.0597	117.2703	23.0	131.7		
Well (117)	WW	34.0588	117.2703	23.0	177.4		
Well (116)	WW	34.0580	117.2703	23.0	162.8		
Well 1S/4W-26F2 S	WW	34.0572	117.2737	W	194.2		
Well (115)	WW	34.0535	117.2730	24.0	200.0		
"Arroyo Verde Well" 1	WW	34.1182	117.2472	H	197.6		
"Arroyo Verde Well" 2	WW	34.1182	117.2472	W	91.5		
De Luz Warm Springs	SP	33.4358	117.3250	29.0		19	290
Agua Tibia Sp. Well	SW	33.3665	117.3910	36.0	217.0		338
Well 10S/1W-23N1 S	WW	33.2878	116.9587	27.0			300
Warner Hot Springs	SP	33.2838	116.6308	56.0		500	244
Well 12S/2W-17H1 S	WW	33.1320	117.1028	27.0			940
Vallecitos Spring	SP	32.9703	116.4230	26.0		19	920
Agua Caliente Springs	SP	32.9483	116.3040	37.0		56	330
Raymond Rasco Well	WW	32.6200	116.1583	31.0	49.0		58

Source Name	Type	Latitude	Longitude	Temp(˚C)	Depth(m)	Flow(L/min)	TDS
Jacumba Hot Springs	SP	32.6158	116.1922	38.0		57	310
Henry Lazare Well	WW	32.6162	116.2920	38.0	61.0		81
Well 17S/5E-3R1 S	WW	32.7203	116.4550	30.0			330
Well 15S/1W-14Q1 S	WW	32.8627	116.9510	31.0			1090
Well 16S/2W-16C1 S	WW	32.7861	117.0940	27.0			2210
Well 18S/2E-14E1 S	WW	32.6088	116.7520	27.0			1050
Well 18S/2W-28L1 S	WW	32.5733	117.0933	27.0			2550
Well 18S/2W-21H1 S	WW	32.5917	117.0858	28.0			1275
Well 18S/2W-28P1 S	WW	32.5710	117.0945	36.0	530.0		1000
Well 18S/2W-33L10 S	WW	32.5583	117.0925	36.0			1390
Well 18S/1W-31H1 S	WW	32.5629	117.0163	33.0	351.0		1475
Well 18S/1W-34N1 S	WW	32.5563	116.9788	28.0	431.0		1400
Well 19S/1W-3E1 S	WW	32.5487	116.9750	28.0	427.0		870
Well 15S/2W-19D1 S	WW	32.8592	117.1330	25.6			
Well 15S/1W-27G1 S	WW	32.8404	116.9681	27.8			
Well 15S/1W-27G5 S	WW	32.8404	116.9681	28.9			
Well 16S/3W-16Q1 S	WW	32.7753	117.1931	25.6			
Well 16S/3W-16R1 S	WW	32.7755	117.1885	25.6			
Well 16S/2W-16D3 S	WW	32.7861	117.0983	25.6			
Well 16S/2W-18L1 S	WW	32.7787	117.1283	27.8			
Well 16S/3W-22P1 S	WW	32.7607	117.1797	26.1			
Well 17S/2W-4B1 S	WW	32.7278	117.0898	25.6			
Well 17S/2W-15J1 S	WW	32.6914	117.0680	26.1			
Well 18S/2W-24M1 S	WW	32.5892	117.0466	28.3	88.4		
Well 18S/2W-27G1 S	WW	32.5779	117.0728	25.6			
Well 19S/2W-1N6 S	WW	32.5414	117.0467	25.6			
Well 15S/3W-32 S	OIL	32.8220	117.2191	73.3	1855.0		
Rohr Ind.s 18S/2W-9F S	TG	32.6219	117.0952	33.1	348.5		
Well 18S/2W-21 S	OIL	32.5865	117.0983	60.0	1677.0		
Well 18S/2W-32 S	OIL	32.5573	117.1059	H	1934.0		
Unnamed Well	WW	32.5842	117.0873	26.7	61.0		
Unnamed Well	WW	32.5724	117.0927	43.3	533.5		
Unnamed Well	WW	32.5845	117.0696	26.7	122.0		
Paso Robles Artesian Sp.	SP	35.6625	120.6917	39.0		380	1400
Paso Robles Mud Bath Sps.	SP	35.6570	120.6945	42.0		360	2370
Unnamed Spring	SP	35.6492	120.6868	42.0		760	1310
Well 26S/13E-11L1 M	WW	35.6792	120.5433	31.0	630.0		600
Well 26S/12E-29C M	WW	35.6447	120.7035	32.7	185.0		1310
Unnamed Well	WW	35.6417	120.6458	W			
Santa Ysabel Springs	SP	35.5822	120.6645	33.0		190	900
Paso Robles City Baths	SW	35.6253	120.6880	38.0	122.0	568	1480
Calaqua No.1	X	35.5838	120.5458	47.0	316.0		
Cameta Warm Spring	SP	35.4000	120.2500	23.0		11	
Pecho Warm Springs	SP	35.2692	120.8570	35.0		65	
Sycamore Hot Sps. Well	OIL	35.1867	120.7133	24.0	286.0		540
Avila Hot Springs Well	WW	35.1808	120.7017	55.0	609.0	189	691

Source Name	Type	Latitude	Longitude	Temp(°C)	Depth(m)	Flow(L/min)	TDS
Newsom Springs	SP	35.1225	120.5430	36.0		57	482
Well 10N/27W-5L1 S	WW	34.9770	119.7930	34.0			1330
Well 7N/35W-17Q1 S	WW	34.6845	120.5848	42.0			5560
Well 5N/33W-31A1 S	WW	34.4778	120.3680	47.0			520
Las Cruces Hot Springs	SP	34.5023	120.2178	36.0		58	565
Well 5N/32W-35F1 S	WW	34.4763	120.2015	31.0			730
Well 5N/30W-32P1 S	WW	34.4647	120.0463	39.0	617.0		2550
Unamed Sp.,Tecolote Tun.	SP	34.5163	119.9042	43.0			300
San Marcos Hot Springs	SP	34.5372	119.8812	43.0		303	420
Unamed Sp.,Tecolote Tun.	SP	34.5103	119.9008	34.0			296
Montecito Hot Springs	SP	34.4625	119.6380	48.0		300	350
Little Caliente Spring	SP	34.5405	119.6195	32.0		57	
Agua Caliente Spring	SP	34.5397	119.5620	56.0		760	685
Boron Spring	SP	34.4228	119.5380	22.0		95	2220
Gaviota Steam Vents	SP	34.4677	120.2783	68.0			
Well 8N/23W-20H1 S	WW	34.7708	119.3333	32.0			440
Willet Hot Springs	SP	34.5820	119.0472	42.0		568	820
Sespe Hot Springs	SP	34.5947	118.9978	90.0		380	1091
Vickers Hot Springs	SP	34.5017	119.3458	51.0		27	1110
Wheelers Hot Springs	SP	34.5092	119.2908	39.0		95	905
Stingleys Hot Springs	SP	34.4995	119.3405	51.0		190	
Matilija Hot Springs	SW	34.4842	119.3072	43.5	5.0	250	272

Appendix 3 Interviews

Belay, Dr. Ahma
Earthrise Nutritionals
760-348-5027x21

Earthrise grows algae for nutritional supplements in ponds in the Imperial Valley. They currently use water from the Colorado River to feed the ponds that they grow their algae in. The algae needs consistently warm water to grow in. Because of that, Earthrise halts growth for 5 months during the winter because of cooler temperatures. Geothermal could provide heating through heat exchange or, if the resource is pure enough, by providing direct flow into the ponds to as both a heating source and water source. George Ray speculated that geothermal waters could be excellent for algae growth due to the high CO2 content. Dr. Belay is interested in geothermal and knowing more about how it could benefit his operation.

Bethel’s Propane
530-233-2134

Bethel’s Propane was contacted for the current price of propane, which is $1.55/gallon.

Booth, Martin
Geothermal Development Associates
775-825-5800

Mr. Booth was contacted for information on geothermal direct-use. He ranked Heating/District Heating and Industrial/Commercial use as the most likely direct-use applications in California. He believed that to have greenhouse applications, operations comfortable with the current energy situation would be needed. Also, a good labor market available is necessary. He considers greenhouses to be a good direct-use application. He also considered commercial food drying a good application; however it needs a 300F resource. Mr. Booth considers an entrepreneurial advocate, very important for a direct-use project because of the level of contact one must have with government and other persons as compared to conventional technologies. He considered the lack of initial cash available and the level of involvement by many persons to be a barrier to direct-use.

Cabanas, Sergio
Geothermal Association of Imperial County
760-353-9630 x309

Mr. Cabanas was contacted to find out more information about geothermal direct-use in the Imperial Valley. However, his expertise is in geothermal electric, not direct-use. He is employed by Ormat in Heber, CA at a geothermal electric power plant. The use of geothermal waters that is discarded after the steam turbine generator cycle was discussed. This discarded water is purer than drinking water with the exception of higher ammonia levels. One possibility could be using the waste water in an aquaculture application and then flowing that water into surrounding agricultural fields after being used in aquaculture ponds.

Cabanilla, R.
Imperial County Planning Commission
760-482-4313

Mr. Cabanilla was contacted for information on the permitting process necessary through the Imperial County Planning Commission. He provided faxed documents regarding permitting and pertinent laws. Those documents were only available through the Planning Commission by fax and for a nominal fee.

Cardenas, Fred
City of Paso Robles
Public Works
805-237-3861

Mr. Cardenas was contacted for more information on a geothermal spring that developed after the earthquake in the area in December of 2003. The spring is in a city parking lot and the flow is currently being diverted into the Salinas River. The city has submitted proposals to the CEC regarding possible geothermal direct-use of the resource, including spa and space heating.

Daniels, John
Bridgeport Public Works
760-932-7251

Mr. Daniels was included as a contact for information about the Bridgeport district heating project, since the Bridgeport Public Works is responsible for that project. Was unable to contact.

Eglington, Mark
Blue Beyond Fisheries
760-329-2878

Another aquaculture geothermal user. Was unable to contact.

Engler, Bill
Tilapia Fish Farms
760-354-1533

Mr. Engler was contacted for more information on geothermal aquaculture. He operates an aquaculture farm in Imperial County and raises tilapia fish. These fish are more sensitive than most in that they will die in waters below 50C. His facility has a geothermal well with 140F water that flows directly into the fish ponds. The water is pure enough so that he can use it for all his water needs. There is no other source of water for the facility. Mr. Engler has been operating this facility for twenty years. According to him, there are other aquaculture farms in the area that have 80F geothermal resources and they grow other types of fish due to the cooler temperature waters. The other facilities typically use greenhouses for additional heat. Some difficulties he believes that are typical to geothermal in his area are the costs of well construction, the uncertainty of source quality before drilling, and permitting. The Imperial County Planning Commission is exceptionally difficult to deal with. The expensive permitting process has to be completed every three years and has been used as reasons to inspect other aspects of his facility, not just the geothermal system. When asked about possible incentives that could be provided to provide geothermal development, he considered anything that could be provided to help mitigate the cost and uncertainly of geothermal resource development could be beneficial.

Erdman, Dennis
Mammoth Community Water District
760-934-2596

Mr. Erdman was contacted for more information on the geothermal district heating proposed project for Mammoth Lakes. The project is proposed to use the wastewater from the Mammoth-Pacific geothermal power plant located 3 miles from the community of Mammoth Lakes. A full investigation was done a few years ago and the project has not gone any farther than a planning stage. The project is waiting for funding from the parent company of the power plant. Mr. Erdman believes there is a large potential in the area for geothermal use. There are plans to convert current and new property to use geothermal for heating from a district distribution system in the next five to ten years. He rates the ability to bring on new customers into a district heating project as very high. There is a high awareness of the possibility to use geothermal resources on the government level, and to a lesser degree, developers in the area. Developers have tended to avoid geothermal heating due to the higher initial cost when compared to other forms of heating - especially for properties they don't plan on owning for a long term.

The town of Mammoth Lakes has recently installed piping in new sidewalks that would allow for snow melting, but there is no district heating system yet to warm the sidewalks. The biggest barrier to the project is funding the system to deliver a hot water source to the core township of Mammoth Lakes. Since the power plant is 3 miles away, it is a significant investment to create the hot water transmission pipes. Mr. Erdman recommends government incentives that provide a quicker depreciation on the increased cost of geothermal and the same sort of incentives that are placed on solar systems by the state that allowed solar to come into the mainstream. Also, incentives for residents to give up their wood burning stoves would help the project as well as improve air quality in the area.

Mr. Erdman believes the stability of the hot water source would affect decisions to switch to geothermal. Historically, the well at the Mammoth-Pacific power plant has shown to be very stable. Another possibility has been drilling another well closer to the township to eliminate the need of the long pipe run and possibly reduce the cost of the system that way. Environmental factors could affect the project, but past history leads to the conclusion that there wouldn't be a negative environmental impact from the project. Most of the residents of the area are supportive of the project.

Geo-Heat Center
Oregon Institute of Technology
Gene Culver
John Lund
Toni Boyd
541-885-1750

Experts at the Geo-Heat Center were contacted for their knowledge of geothermal direct-use. They were asked to rank direct-use applications by the expected interest in those applications in California. The experts ranked applications as follows: 1) aquaculture, 2) greenhouses, 3) Industrial/Commercial Use tied with Heating/District Heating, and 4) Hot Springs and Spas. For Industrial/Commercial direct-use, the experts believed that those applications required higher temperatures than what is typically used for direct-use. High temperature resources, such as those needed for Industrial and Commercial use, are more easily used for electricity production than direct-use. For Heating/District Heating, the experts and the Geo-Heat center said that there is a possibility for district heating in Bridgeport and Mammoth Lakes.

These experts considered a "hero", someone who was invested in a direct-use project and could push the project through all the difficulties inherent with direct-use and had knowledge of geothermal and the application, as very important to the success of the project. Other considerations that they thought could have a positive or negative effect on direct-use were: the reduced toll for geothermal use on federal lands; regulatory issues, such as the stricter water quality requirements on arsenic and mercury; the rose flower industry being destroyed in the US by foreign competition; high natural gas prices; high initial costs of geothermal; and, the difficulty in finding a reliable source.

Hill, Roger
Sandia National Laboratories
505-844-6111

Mr. Hill was contacted for general information on geothermal direct-use. He provided useful information, however, by the time he was contacted, given information has already been discovered from other resources.

Hodgeson, Susan
California Department of Conservation
Division of Gas, Oil & Geothermal
916-323-2731

Ms. Hodgeson believes that the use of geothermal will depend on the state of the economy. She does not believe that geothermal direct-use will either increase or decrease dramatically.

Intyre, Mike
San Bernardino Water District
San Bernardino Wastewater Treatment Plant
909-906-7610

Mr. Intyre was contacted for more information on geothermal use in the San Bernardino Wastewater Treatment Plant. In a past CEC project, geothermal heating was implemented in a wastewater treatment process with possible expansion of its use. However, the treatment plant has since quit using geothermal in its water treatment and only uses geothermal for space heating. A soon to be implemented co-generation system will provide all necessary heat for treatment. There is no expected or possible need for geothermal in the treatment plant facilities.

Johnson, Elizabeth
California Department of Conservation
Division of Oil, Gas & Geothermal
District 1
916-323-1786

Ms. Johnson was contacted for information on the permitting process for geothermal direct-use and possible pending direct-use projects in her region. The California Department of Conservation provides permits for well drilling on private or state land. The Bureau of Land Management and the National Forest Service provide permits for drilling on their respective lands. For mineral right leases, the State Lands Commission, BLM, NFS, or whoever the mineral rights owner would be would provide such leases. The last project in her region was a district heating project done by I'SOT in Canby, CA. Dale Merrick was the project manager, who was also contacted. Any direct-use projects prior to the I'SOT project, were 15 years ago in the Susanville, CA area. A prison and school in Susanville are heated by direct-use, as is a hospital in Greenville and a school in Alturas. She is unaware of any other pending or potential projects in her region.

Ms. Johnson considered Hot Springs and Spas to be the most likely direct-use application to have growth in the near future because such applications are the least expensive to do. She believed that there was only a 20 percent chance of new aquaculture in her region. District Heating is unlikely because there is no community in her region that supports it. There have been many studies done in Mammoth

Lakes, but there is no hero there to support such a project. There is a heating system in the prison at Susanville, but the operators there don't like it. They prefer natural gas as it is easier to understand. Users there are also worried about the surface level disposal of geothermal waters as they believe they may have a future liability. Barriers that she considers affecting geothermal direct-use are: natural gas is cheaper; people don't know about direct-use or how to use it; a "hero" is necessary to get through all the paperwork, raise money, convince government entities, get permitting, etc.

Katz, Bob
EASI Demographics
718-740-7930

Mr. Katz was contacted for more information on the EASI Quality of Life Index. The information he provided has been included in this report.

Khan, Ali
California Department of Conservation
Division of Oil, Gas & Geothermal
District 3

Mr. Khan was contacted for information on the permitting process for geothermal direct-use and potential direct-use projects in his region. The only direct-use projects in his region are hotel and spas in the Calistoga area. Most of the wells there are old enough that they were created without any permitting. Also, for any resource cooler than 86C, permitting through the CDOC is not necessary. Those lower temperature resources are permitted through the Department of Water Resources.

Lovekin, James
Geothermex
510-527-9876

Mr. Lovekin was contacted for information on geothermal direct-use. He was asked to rank applications for their likelihood of growth in California. He ranked applications as follows: 1) Heating/District Heating, 2) Industrial/Commercial Use, 3) Greenhouses, 4) Aquaculture, and 5) Hot Springs and Spas. He ranked Heating/District heating highest because it has the broadest base of customers. He cited Iceland using discharge from geothermal electric plants as a leading new application. He believes that district heating is the trend of the future because heating of single buildings is too expensive and risky. He considers the initial costs of drilling and capital to be major barriers to direct-use. He believes that grants and tax breaks should be available for direct-use. The low cost of natural gas is another barrier to direct-use.

Lowe, Steven
760-251-6470

Mr. Lowe is a permittee applicant for created a resource to use in a hotel spa in Desert Hot Springs, CA. Contact with Mr. Lowe was not possible.

Lyster, Dan
Bridgeport, CA
District Heating Project - Former Manager
760-924-1705

Mr. Lyster was contacted in regards to the Bridgeport geothermal district heating project discussed in CEC report P500-82-049. Apparently, after a well was drilled, the resource was found to not be warm enough to support the proposed district heating project. The Bridgeport water district has applied for a grant to do additional exploration in an attempt to create a warmer source, but nothing has happened recently.

Malan, Justin
California Aquaculture Association
Executive Director
916-944-7315

Mr. Malan was contacted to find aquaculture users he represented that used or desired to use geothermal direct-use in their operations. He provided the names of two users who were later contacted.

McCahon Nurseries
Purchased Nakashima Nurseries

McCahon Nurseries was contacted because Nakashima Nurseries was listed in the Geo-Heat Center site as a geothermal direct-user. However, McCahon Nurseries provided information that none of their greenhouses use geothermal heat.

Mealey, Kathryn
California Cut Flowers Commission
831-728-7333

Contact with Ms. Mealey was attempted in an attempt to get names of users in the greenhouse grower industry that used geothermal heating in their facility. Was unable to contact.

Merrick, Dale
I'SOT
530-233-5151

Mr. Merrick was contacted for more information on the district heating project in Canby, CA for I'SOT that is partially funded by the CEC and DOE. I'SOT is also interested in other geothermal applications in the future. Mr. Merrick is the project manager for the district heating project in Canby. The project has just recently been completed and is functioning. He believes there are possible applications in Canby for geothermal greenhouses, aquaculture and additional district heating. Agencies that were involved in the process of the district heating installation were: The Department of Conservation - Division of Oil, Gas, & Geothermal, the Water Board, U.S. Fish & Wildlife, Department of Fish & Game, the County Planning Department, and the Environmental Health Department.

Mr. Merrick and I'SOT are considering putting in a small geothermal electric plant nearby for providing for their electricity needs. The expected resource for that plant would be 500gal/min at 223F for a well drilled to 3000 ft. The expected temperature of the wastewater after electricity production would be 145F. They would like to use that wastewater for heating of greenhouse and aquaculture facilities. Their plans are to drill a new well at the current power sub-station which is 1500' from the current well. Greenhouse and Aquaculture facilities would be located within 1000' of the new well. The idea is for a cascading use system which uses geothermal for electricity production and then uses the remaining waste hot water for direct-use in aquaculture and greenhouse heating. The land around the proposed well is all agriculture, so it could easily be converted for use in both aquaculture and greenhouses.

I'SOT's proposed partner for Aquaculture is Ron Kettler of Kelly Hot Springs. He raises Bass and Catfish and has a Tilapia license. His current production is at 12,000 lbs/acre.

Their other options for energy are electricity, provided by Surprise Valley Electric at approximately 6.1¢/kWh and PPNL at around 11¢/kWh, or propane, which is provided by Bethel's Propane.

Monastero, Dr. Frank
United States Navy
Geothermal Program Office
760-939-4046

Dr. Monastero was contacted in regards to geothermal direct-use on U.S. military facilities. He provided a report that was completed by Innovative Technical Solutions, Inc for NAWS China Lake in October of 2003. Information from that report is included in this report and referenced in the bibliography.

Moynier, John
EIP Associates and
Mammoth Community Water District
916-325-4800

There are two projects that John Moynier was involved in Mammoth Lakes as a project manager through the Mammoth Community Water District. One was a cooling project; the cooling of waste heat water from the Mammoth-Pacific Power Plant. The other was a direct-use project for the town of Mammoth Lakes. It would use either a redundant well at the power plant or their waste heat from electricity production. The direct-use project would involve commercial and residential space heating and snow melting.

Two reports have been written recently on the potential direct-use in the Mammoth Lakes area, looking at the phasing of the project and potential heat load, one was by Black & Veach and the second was by Kattner/F.E.B. Both of these studies found that the heat source being two miles away from the community was essentially too far away from the load to justify the project. The cost of the pipeline couldn't be amortized with the limited heat load identified for the project. If a heat source closer to town could be developed, which Mammoth-Pacific is currently trying to do through exploratory drilling, then the economics of the project would change. The first phase of the project would be district heating for public users, such as the waste water agency, community college, schools, hospital, town offices, and forest service offices. There would be a few residential customers picked up with that first phase. The second phase would be a snow melting system, for which some of the infrastructure is already installed. There are pipes placed in sidewalks installed in the last two summers that are ready for use in a snow melting project. The third phase would be a combined project with CalTrans to put in a snow melting system on Highway 203 coming into Mammoth from 395. That project was on CalTrans' R&D calendar, looking at it as a pilot project for other snow melting projects. The final phase would be connecting other residential and commercial areas to the district heating system. The first phase didn't show enough of a heat load to justify the pipeline from the power plant source.

Mammoth-Pacific was very interested in cooperating on this project for two reasons; one was from a community interest point of view, but secondly, they saw it as a reciprocal project, to deliver a heat source to the community and in return, receive treated waste water for cooling of their power plant. Their plant is currently air-cooled which affects their efficiency, especially in the summer time. The Mammoth-Pacific power plant is actively pursuing other heat source wells, due to leasing constraints on their current wells, as well as for redundancy and possible plant expansion. They have 20 year development leases which will expire in the next five years, so they want to make use of those before they expire.

There is strong community support in the area for a district heating system, though there are no formal commitments. InterWest, the largest developer in the area, is very interested in it; however, they are the furthest from the heat source, and would most likely be the last to be connected to a district heating system. Interest from public sources was very high; the condominium community was also interested, however they were concerned over the capital costs of connecting to the system.

Most of the condominiums are electric heat, so there is no installed forced air heating systems, which makes the installation of the hardware for a district heating system in those buildings expensive and fairly invasive. These residential customers were interested in reducing their heating bills, but were concerned with capital costs. So from there, the concern would be - does the project take on the capital costs to retrofit? Do you amortize those costs over a 30 year period? Do you include these costs in their rate charges? These questions have been left open for now. In the Kattner report, they did some community surveying and found that typically, customers were interested in being part of such a district heating system if their heating costs could be reduced by half. A 50 percent reduction would not be difficult for those customers who are on electric heating, though it could be difficult for those that use propane.

The elected board of the MCWD was interested in pursuing this district heating system, but they wanted to see some assistance, either from the state or the federal government. The project was online to be part of the "GeoPowering the West Initiative", back with the previous administration The Mammoth community was going to be the poster child for their program, but has fallen through with the current administration. There has also been discussion with the CEC about a grant, either a cooperative grant with the Mammoth Pacific power plant or stand-alone, but that money went away as well. This lack of funding has been systematic of this project. There have been 25 years of studies on the possibilities of such a project, where everyone says it's a great idea if you can get the dollars to balance, but the dollars have yet to balance. There is lots of high temperature potential for electricity production in the area, but there is also large potential for lower temperature water that would be highly conducive to a district heating system.

The community has begun to lose interest in such a district heating project due to many years of talk of such a project without any actual headway. Another current barrier is that the Mammoth-Pacific's parent company, Covana, is bankrupt. They are up for sale, so it would depend on how interested the new owner would be in entering into a cooperative agreement such as the plans that have been previously made. Otherwise it might end up being an individual developer drilling their own independent wells. The MCWD has looked into drilling their own limited use wells, but they are looking for some sort of outside funding support. The MCWD has the money to enter into such a project, collected from discressionary property tax revenue that is committed to the project, and they can also apply for low-interest loans because they are in good financially standing. The MCWD is poised to start on the system, but is looking for state or federal assistance to make the extra push. There has been preliminary engineering done for this system, such as heat load distribution and piping.

An additional barrier could be the propane operators in the area that are looking to block such a district heating project. These operators are looking to install a propane distribution system and the installation of a district heating project would negatively affect their business. Their political stance asks why a public agency should be taking business away from private entities. There is no natural gas delivery system in the Mammoth Lakes community, which leaves the current options being wood-burning stoves, which have created an air quality issue in winter time, propane, which is from tank storage, and electricity. Other barriers to such a system are that there is very little experience in the US with such district heating systems. Klamath Falls is really one of the only local systems that can be used as an example. (It was pointed out by Gene Culver of the Geo-Heat Center that there are other examples of geothermal district heating in: Boise, Idaho; Elko, Nevada; and others for a total of 18 in the U.S.)

Norwood, Susan
U.S. Department of Energy
GeoPowering the West Initiative
202-586-4479

Ms. Norwood is inactive with the DOE until August working on a different project. Roger Hill of Sandia National Labs was provided as an alternate contact.

Osborne, Will
Cal Energy
760-348-4214

Mr. Osborne was contacted for information on Cal Energy's mineral extraction operation in the Imperial Valley. Cal Energy operates a geothermal electric power plant in the Imperial Valley. The geothermal waters used are very high TDS brine with a rare, high concentration of metals. Currently Cal Energy extracts zinc and silica from the geothermal brine, however they are considering expanding to manganese, boron and lithium. The extraction is done by a chemical process.

There are expectations to expand both extraction of zinc to new power plants and the extraction of manganese to current and new power plants. Units 1 through 5 currently have zinc extraction processes. Plants that are considered for construction are units 6 and 7. There has been a pilot project where manganese has been extracted and the CEC was involved in that project. The cost of the zinc extraction process is not publicly available, but it is competitive with the zinc market.

Pierce, Susan
City of Huntington Beach
714-536-5271

The city of Huntington Beach was contacted for more in formation on the study of using geothermal wastewater for applications within the city. The report cited is CEC report 912-81-017. However, no one listed in the report from the city is still there and no one else at the city government knows about the report.

Rafferty, Kevin

formerly of the Geo-Heat Center

Mr. Rafferty was contacted for information on geothermal direct-use applications. He considers District Heating to be uneconomical, with costs usually $2-5/square foot. District Heating usually needs other unique factors to be successful. He considers aquaculture growth to have leveled off and that transportation is an issue for such applications. Greenhouse applications are a good. He believes direct-use will grow in areas where development already exists. Exploration costs are usually outside of the recoverable costs in direct-use.

Ray, George
Catfish Aquaculture
760-359-3474

Mr. Ray is the owner and operator of Catfish Aquaculture farm in the Imperial Valley. He was contacted for more information on geothermal direct-use in aquaculture. His facility has 3 900ft deep wells that provide approximately 100 gallons/minute that is blended with Colorado River water to supply fresh water for the fish ponds. The resource is 117F, which is not warm enough to provide significant heating for the volume of their ponds, however catfish do not need the warmer temperatures that are required by other fish. The water from the geothermal wells has some sort of content that negatively affects the fish, hence the blending with Colorado River water.

Mr. Ray suggested a project for geothermal could be growing algae. A nearby business, Earth Rise Farms, grows algae from Colorado River water. He believes a geothermal resource such as his, with moderate temperatures and relatively high salt content (3000ppm), would work well for such an operation. Mr. Ray believes that it would be beneficial for the government to assist with improving the use of wells and with water analysis to help negate the negative effect the geothermal waters has on the fish. He believes that the redistribution of Colorado River rights transferring from the Imperial Valley to San Diego could have a positive effect on geothermal in the area. With less Colorado River water to use, many operations will need other sources of water.

Remmers, Harry
US Department of Interior
Bureau of Reclamation
Technical Service Center
303-445-2261

Mr. Remmers provided information about Reclamation's geothermal driven Vertical Tube Evaporator (VTE) desalination project at the Salton Sea. Mr. Remmers has played a significant role in developing plans for the project. VTE desalination produces approximately 80 percent of total feed water volume as fresh water and the other 20 percent as concentrated saltwater brine. That brine can either be disposed of by: having the water evaporate off in ponds, or by injecting it into the geothermal aquifer. A certain percentage of the geothermal brine must be returned to the aquifer according to the regulatory leases and permits, and the concentrate from the VTE process can help meet that requirement.

The goal of the Salton Sea desalination project is to reduce the salinity of the Sea from the current level of 44,500 mg/L to less than 44,000 mg/L within 20 to 30 years. For this to be accomplished, 60 million tons of salt must be removed, as well as the 4 million tons of new salt that flows into the Sea each year. To meet these requirements, approximately 114 MGD of Sea water would have to be treated. A desalination project of this size would be constructed as part of CalEnergy Company's Unit 7 development effort, which used for just electricity, will produce approximately 175 MW, or as dual use, would produce 80MW of electricity and 2.85 million lbs/hr of 2-psig (217 ºF) steam.

There are plans to build a VTE facility capable of treating 20 MGD of Sea water that would be designed to operate off the 500,000 lbs/hr of waste steam available from CalEnergy Company's existing geothermal plants. The proposed Unit 7 at CalEnergy Company would make much more efficient use of the geothermal steam, and there would not be any "waste" steam available from this new power plant. Steam for desalination would have to be purchased from CalEnergy Company at a rate of $3.48 per ton of steam on its value in producing electricity at 7.5¢/kWh.

Rosenberg, Mark
California Department of Forestry

Mr. Rosenberg was contacted to confirm that the location data for geothermal resources included in this report was compatible with the Department of Forestry's GIS mapping software. Compatibility was insured by including longitude/latitude data in decimal degrees.

Simmons, Brenda
City of Twentynine Palms
760-367-6799

The City of Twentynine Palms was contacted for more information on geothermal exploration that was completed and reported in CEC report 912-86-005. However, no one at the city government has more information than what is provided in the report.

Smith, Mike
California Energy Commission

Mr. Smith was contacted for information on geothermal projects he was involved in previously. He provided information that no additional activity has been completed on the City of Huntington Beach geothermal using wastewater study shown in CEC report 912-81-017.

Spurr, Mark
Kattner FVB
612-607-4544

Mr. Spurr was contacted in regards to a report that Kattner FVB produced that provided an economic assessment of the proposed Mammoth Lakes geothermal district heating project. He provided an electronic copy of the executive summary from that report.

Trily, J.T.
Fountain of Youth Spas
858-459-2754

Mr. Trily is the owner and developer of the Fountain of Youth Spas, a facility in the Imperial Valley that has spas and RV resort. The facility uses geothermal for spas and water heating. He was contacted for more information on geothermal direct-use in hot springs and spas. There are other spas like his as well as aquaculture farms in the area that use geothermal. One barrier Mr. Trily saw to future geothermal use was the difficult and expensive permitting process. In 1964, when he started the business, there were no regulatory issues to deal with during installation. There are now many more issues and permits that must be gone through for a well. He must provide yearly reports and re-apply for a permit with the Imperial Valley Planning Commission every three years. His last well permit cost him $4000 and took several months. In comparison, the well before that, which was drilled in 1989, cost a couple hundred dollars and very little time. The permitting process with the Imperial Valley Planning Commission tends to involve all aspects of his business and seems to be used as an excuse to look at everything on his property. The state permit process, which must also be completed to drill a well, is simple when compared to the Planning Commission.

Walker, Mike
US Department of Interior
Bureau of Reclamation
Salton Sea Restoration Project
Program Manager
928-343-8243

Mr. Walker was contacted for information on proposed plans for restoration of the Salton Sea. One of the proposed restoration projects was using excess steam from geothermal electric plants on the Sea for VTE (Vertical Tube Evaporation) desalination to reduce the salinity levels. To provide sufficient desalination for restoration, a system that would provide 50 MGD (million gallons per day) of desalination would be required. A test system is being proposed to look at the technology that would provide 5 MGD. The organization that would be providing engineering services is Sephton Water Technology.

Woods, Mike
California Department of Conservation
Division of Oil, Gas & Geothermal
District 2
760-353-9900

Mr. Woods was contacted for information on the permitting process for geothermal direct0use and potential direct-use projects in his region. The most recent activity in his district has been for private and commercial hot spring wells. The most recent permit application was for a hotel hot spring in Desert Hot Springs, CA. Steven Lowe was the applicant, however, he was unreachable using his provided contact information. Other agencies involved with such applications are the County Health Department when it is spas, and the Imperial County Planning Commission, which regulates geothermal resources. Mr. Woods provided information on a resource in Paso Robles that was created by the earthquake in December 2003 that could be a potential source for direct-use. He also provided information on Cal Energy, which draws zinc from waters used in geothermal electric production. He recommended contacting Will Osborne of Cal Energy in regards to that project.

Mr. Woods believes that Hot Springs and Spas are most prevalent in growth in his region. This application is the least expensive and does not require as much expertise. Aquaculture is the second in his region for growth. Most of the applications in his region owe their success to having a previously available source. A barrier to geothermal direct-use in his region is water rights. The Imperial County Planning commission regulates the amount of hot water a user can get from the ground in an effort to control the impact of one geothermal user on another. They have prevented the expansion of direct-use applications for this reason in recent past.

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