Developed by the GeoPowering the West Colorado State Working Group

August 2007

COLORADO GEOTHERMAL DEVELOPMENT: STRATEGIC PLAN

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This report would not have been possible without the hard work of the GeoPowering the West Colorado State Working Group.

STEERING COMMITTEE

Craig Cox, Interwest Energy Alliance
Seth Portner, Colorado Governor's Energy Office
Curtis Framel, U.S. Department of Energy
Matt Sares, Colorado Geological Survey
Dan Phaure, Dundee Securities Corporation
Paul Thomsen, Oramt Technologies
Paul Bony, Delta-Montrose Electric Association
Randy Manion, Western Area Power Administration
David Hiller, Senator Ken Salazar's Office
H.E. "Buzz" Johnson, Enlink Geoenergy Services
Jeff Holwell, Colorado Office of Economic Development
John Bilisoly, Colorado Division of Water Resources
Carsten Mehring, Colorado School of Mines
Susan Innis, Western Resource Advocates
Megan Castle, Colorado Governor's Energy Office
Duane Spencer, Bureau of Land Management
Gary Klug, Colorado Public Utilities Commission

INTRODUCTION

The Colorado Geothermal Development Strategic Plan is an action-oriented document prepared by the GeoPowering the West Colorado State Working Group. The U.S. Department of Energy's (DOE) GeoPowering the West (GPW) initiative is designed to increase the use of geothermal energy by linking the power industry, geothermal users, and governments with technical and institutional support, educational outreach, and limited cost-shared funding.

Geothermal resources are most commonly divided into several categories depending upon the temperature, potential use or geologic setting. A high temperature (>356^{o}F;>180^{o}C) resource can be utilized with conventional turbine technology to produce electricity. Intermediate temperature (194-356^{o}F; 90-180^{o}C) resources are suitable for many industrial heat applications and for electrical power generation using binary-power technology. Low temperature (<194^{o}F;<90^{o}C) resources have uses in space and district heating and in many agricultural applications that require lower grade heat. Geothermal heat pumps rely on the even lower, nearly consistent shallow ground temperature.

Geothermal resources are most easily defined as useable manifestations of the Earth's heat energy and may represent the largest useable energy resource base available to man. Geothermal power production offers several advantages over other renewable energy production sources. Modern closed loop binary systems have virtually no emissions, a small plant footprint, low noise emissions, high reliability, and are base loaded.

Colorado ranks fourth among western states in the number of potential sites for geothermal power generation, according to a 2006 Western Governors Association report. While Colorado has numerous geothermal direct use and aquaculture projects, the state currently has no geothermal electrical generation projects.

The ideas and actions outlined within this plan are designed to accelerate and enable the exploration and development of the state's abundant geothermal resources.

While numerous strategies are presented within this document, foremost among them is the completion of mapping efforts currently underway. By directing limited funds towards identifying the state's best geothermal resources, Colorado will be able to attract the investors and resource specialists necessary to bring generation projects to the state.

Other key recommendations include:

- New state loan guarantees on financing for geothermal energy projects.
- Creation of a state drilling incentive to encourage geothermal exploration.
- Creation of a state production tax credit for geothermal energy production.
- Recognizing ground source heat pumps as a renewable energy source.
- Encouraging electric utilities to pursue ground source heat pumps as part of their demand side management programs under HB-1037.

The geothermal resources within the state can also play a critical role in bolstering rural economies through the creation of new jobs in power generation, agriculture, aquaculture, and construction.

While numerous organizations currently advocate geothermal energy, the working group strongly recommends the creation of a full-time position within a state university or other established entity dedicated to developing and promoting the industry within the state. With uncertain GPW funding in the future, this position would spearhead outreach efforts within the state. This position would be free of lobbying constraints currently in place within state government offices and would be funded by private industry and other sources.

This report also covers the barriers and opportunities faced by the direct use and geothermal heat pump industries, as well as suggested action items. It also addresses needed industry efforts to outreach to key stakeholders to help educate them about the important role geothermal energy plays in our energy future.

By developing Colorado's abundant geothermal resources, the state can continue on its path of creating a widespread renewable energy economy, while helping to limit carbon emissions, ensuring Colorado's splendor remains for future generations to enjoy.

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1.0 STATEWIDE GEOTHERMAL RESOURCE OVERVIEW

GEOTHERMAL RESOURCES - BACKGROUND

In the United States, geothermal power supplies 17 percent of the available *renewable* electricity, but only 0.3 percent of total electricity supply. [i] Coal is the dominant fuel for production of electricity. There is ample opportunity for geothermal power growth, with many states requiring renewable portfolio standards for electric utilities and a general desire to reduce greenhouse gases. Most of the U.S. geothermal power generation takes place in California and Nevada, while Utah, Hawaii, and Alaska produce electricity as well. Additionally Arizona, Idaho, New Mexico, Oregon, Texas, Washington, and Wyoming all have geothermal power projects under some stage of development.[ii]

Unfortunately, Colorado is not found in the above list. It is not because Colorado is lacking in geothermal resource potential – the state has 59 hot spring sites (some with multiple springs) and 34 geothermal well sites.

Currently, many of the geothermal waters at these sites are used directly for input to spas, pools, aquaculture, structure heating, etc., representing savings of conventional thermal heat costs and consumption of fossil fuels. These “direct use” activities bring business opportunities to the local economy.

1.1 CLASSIFICATION OF GEOTHERMAL RESOURCES

Geothermal resources can be classified into three different areas of use: geoexchange (a.k.a. geothermal heat pumps, ground source heat pumps), direct use (pools, spas, greenhouses, aquaculture, etc.) and electrical power generation. The temperature of the geothermal resource required for each of these uses varies.

Geoexchange heating and cooling applications rely only on the background temperature of the earth at shallow depths, which is fairly constant at about 55° F. No thermal anomaly is needed. Therefore, this type of geothermal application can be used anywhere. It is increasingly being used in commercial and public buildings and in residential homes. A selected list of geoexchange in government facilities can be found at the Governor’s Energy Office website: www.colorado.gov/energy.

The geoexchange type of geothermal resource is addressed in more detail in Chapter 3. This chapter will focus more specifically on the geothermal resources necessary for the following two types of resource uses.

Direct use of geothermal resources relies on higher water temperatures in the 100-250° F range. Direct use takes advantage of natural hot springs or thermal water wells and does not use heat pumps or power plants. This heat energy can be used for hot springs pools and spas, space heating for buildings, district heating for entire areas of a community, greenhouses, aquaculture, and light industrial processes requiring heat. Currently, there are at least 40 types of direct use applications of geothermal resources in Colorado. Some individual sites have multiple applications, such as a spa or pool with concurrent space or district heating. Details of direct use in Colorado are addressed in Chapter 2.

Electrical power production requires high temperature geothermal resources. In the past, this has required geothermal resource temperatures above 300°F, but technology has advanced such that lower temperature resources are now available for electrical generation. Higher temperature resources use “direct steam” and “flash steam” geothermal power plants from geothermal resources above 300°F. In the 1980s “binary power plants were implemented that could use lower temperature water, generally above 250° F, to heat a secondary working fluid with a lower boiling point that is then used to drive a turbine.[iii] Recent binary technologies have allowed smaller scale power production at even lower temperatures. Chena Hot Springs in Alaska, for example, has a 400-kilowatt (kW) power plant using 165°F water. These technological developments expand the number of areas that are prospective for electrical power generation from geothermal resources and have enhanced the potential for this type of geothermal resource development in Colorado. Currently, Colorado has no geothermal-sourced electricity generation, but for the first time in almost 25 years, there is keen interest in identifying such a resource. Issues related to the development of electrical power generation are addressed in more detail in Chapter 4.

1.2 COLORADO GEOTHERMAL RESOURCE BASE

Past Geothermal Resource Characterizations

Geothermal energy resources in Colorado were seriously investigated in the late 1970s and early 1980s. This was a result of severe increases in energy costs that prompted funding from the federal government for research and development of new energy sources. On the national level, the effort was dubbed “Project Independence”.[iv] The Colorado Geological Survey produced over 30 publications characterizing the geothermal resources of the state using funding made available by the federal government. Many low and moderate temperature resources were identified in Colorado that are suitable for direct use applications, but no conclusive evidence of a high temperature resource that could be used for electrical power generation was identified.

The Colorado Geological Survey (CGS) study, “1992-1993 Low-Temperature Geothermal Assessment Program, Colorado”[v] is the most recent statewide data gathered on the geothermal resources of Colorado until the current ongoing work. The term “low-temperature” in the report encompasses geothermal water temperatures greater than 30°C (86°F) and less than 90°C (194°F). This report updated a 1978 assessment[vi] and identified 157 geothermal sites including 59 hot spring sites (some with multiple springs) and 34 geothermal well sites. These numbers do not include hot residential water wells or oil and gas wells that are not designated as “geothermal” wells. There are a large number of these “undesignated” wells, which, if identified, would enlarge the extent of some geothermal resource areas. The 1992-93 assessment increased by 25 percent the number of geothermal sites identified in the 1978 assessment (125 sites). A reassessment of subsurface geothermal reservoir temperatures through geochemical analysis was not performed during the 1992-93 study. It was noted that among the 10 new water quality analyses done, there were no significant changes from previous water sample results. The sites identified in the report have not been revisited since the early 1990s.

Colorado is Prospective for Additional Geothermal Resources
Colorado exhibits important geologic criteria indicative of geothermal resources with power generation potential. These include:

- **High Heat Flow –** Colorado has the second largest areal heat flow anomaly in North America with heat flow values greater than 100 milliwatts per meter squared (Figure 1). This high heat flow area predominantly coincides with the mountainous central and western portion of Colorado. The average worldwide heat flow is 59 milliwatts per meter squared.[vii]
- **Volcanism –** Colorado has had significant volcanism within the last 23 million years (Neogene and Quaternary; Figure 2). Indeed, five volcanoes in Colorado are less than 2 million years old and the Dotsero Volcano has been dated at 4,150 years ago[viii].
- **Recent Faulting –** Colorado has over 90 faults that have been active within the past 2 million years (Quaternary; Figure 2).[ix] Younger faults have more geothermal potential.
- **Continental Rifting –** The Rio Grande rift zone extends through Colorado from the San Luis Valley north to at least Leadville and perhaps further into northwest Colorado. Rift zones are important geothermal resource areas in the western U.S..

Another interesting line of evidence pointing to the potential for geothermal resources considers the velocity of seismic P-waves. A geographic map of tomographic P-wave velocity variations indicates that P-waves are markedly slower in central Colorado (Figure 3)[x]. P-waves have lower velocity as they pass through areas where the Earth's crust and upper mantle are warmer and/or more fluid. The P-wave anomaly in Colorado, informally called the Aspen anomaly, appears comparable to the Yellowstone anomaly. The interpretation of a warmer crust and upper mantle in the area of central Colorado's Aspen anomaly would enhance the probability of a greater geothermal gradient in that area.

Oil and gas development in Colorado has also indicated geothermal resource potential in two structural basins – the Denver Basin and the San Juan Basin. Many oil and gas fields in the Denver basin have recorded bottom-hole temperatures ranging between 200-250°F (93-121°C) at roughly 10,000-11,000 feet. While some of these resources may not be hot enough to supply energy to the grid, there is potential they could produce enough energy to power the field's oil and gas pumps.

Bottom-hole temperatures in the San Juan Mountains outside of Durango have also been measured with relatively high temperatures ranging from 150-250°F (65-121°C) at depths between 6,500 – 9,000 feet.

Many of the sites identified in the CGS 1992-93 assessment may hold untapped potential considering the recent technological advancements in geothermal power plants. New data from various sources such as oil and gas wells, mineral development drilling (e.g. coal), and water wells can help confirm geothermal prospects identified in previous studies or identify new sites in relatively unexplored areas.

Earlier it was noted that in Alaska electricity is produced from 165°F (74°C) water via a binary power plant. Colorado has five hot springs or wells with temperatures above 165°F. They are all located in central Colorado in the Mount Princeton and Waunita Hot Springs areas. This situation is mentioned to illustrate that it is technically feasible to produce electricity in Colorado now, although the competitive electricity market in the state (as compared to Alaska) makes this economically difficult.

Colorado's high altitude also allows boiling water (vapor pressure ≥ atmospheric pressure) to be achieved at lower temperatures. This fact could make Colorado geothermal resources more attractive as thermal waters can be "flashed" at lower temperature. At 8,000 feet altitude – the proximal altitude of many mountain hot springs – water boils at almost 15°F lower than at sea-level.[xi]

Current Geothermal Resource Characterization
Currently, the Colorado Geological Survey is compiling a Colorado-specific geothermal database using national geothermal data sources; selected wells with good-quality geothermal data; and newly released data, such as AMAX Corporation's Buena Vista - Mount Princeton area geothermal data from late 1970s and early 1980s. This newly compiled and re-evaluated data is being used to create a new, more detailed **statewide heat flow map** (Figure 1). Heat flow is a measurement of the rate that heat moves through the Earth and is a strong indicator of geothermal resource potential at depth.

In addition, bottom-hole temperature and drill-stem test data from oil and gas wells are being combined with geothermal gradient data from the heat flow database to create a **statewide geothermal gradient map** (Figure 4)**.** A geothermal gradient map is useful in identifying prospective areas for geothermal energy exploitation, as it quantifies the rate of increase in temperature with depth in the Earth.

From the preliminary heat flow and geothermal gradient maps, several areas can be identified that have potential for geothermal power generation. These locations include the Mt. Princeton area near Buena Vista, the Waunita Hot Springs area in southeast Gunnison County, the San Luis Basin especially along its margins, the San Juan Mountains near Ouray and Rico, Pagosa Springs, the Raton Basin west of Trinidad, and possibly an area near Somerset. Also, past geothermal and geochemistry studies at hot springs in the Steamboat Springs area indicate geothermal resources at depth may have temperatures above 250°F (125°C).

The Massachusetts Institute of Technology (MIT) Geothermal Study
In early 2007, MIT released a report called "The Future of Geothermal Energy." The report discusses the ability of "enhanced" geothermal systems (EGS) to meet long-term

electrical power needs in the U.S. Enhanced geothermal systems are engineered reservoirs (enhanced through induced fracturing and other processes) that are created to extract economical amounts of heat from low-permeability geothermal resources.[xii] It is essentially heat mining. The study concludes that with a reasonable R&D investment, EGS could provide100 gigawatts, or 10 percent of the nation's electrical demand within the next 50 years.

Enhanced geothermal systems would work well in the crystalline rock areas of Colorado that have high heat flow. Enhancing the geothermal reservoir and heat-mining could allow significant electrical power generation.

MIT made calculations concerning the amount of energy available at various temperatures and depths for each state. Colorado consistently ranks 1st in the amount of energy available from the hottest temperature resources available in the 4.5 (~14,800 ft) through 9.5 km (~31,200 ft) depth range. Colorado ranks 5th among the states regarding total potential amount of energy available from EGS with just less than 800,000 exajoules.[xiii] One exajoule is equivalent to: 160 million barrels of oil, or 277,800 gigawatt-hours.

1.3 RECOMMENDATIONS FOR NEW GEOTHERMAL RESOURCE CHARACTERIZATION

Past geothermal studies in Colorado are a great resource for the renewed interest in renewable geothermal energy today, but much more work needs to be done to attract private sector interest and investment in developing the state's geothermal resources.

Colorado needs to have a dedicated geothermal research, field investigation, and education/outreach entity with stable funding. The Colorado Geological Survey has served in this capacity and continues to do so, although current funding and staff levels are limited. Federal funding for geothermal research has declined over the last 5 years and was essentially non-existent in the 2006-07 federal budget. To take advantage of geothermal resources, the private sector needs to have the base scientific information to evaluate the possibilities of a successful venture. Additional studies in key geothermal areas will be important in this regard and funding is necessary to perform these studies.

In light of new technology allowing lower temperature resources the ability to produce electrical power and the Colorado renewable portfolio standard of 20 percent by 2020, a full re-evaluation of geothermal resource potential for power generation is needed. A compilation of the geologic characteristics of notable geothermal systems in Colorado and a comparison to known producing geothermal systems around the world is needed. Through an examination of the geology, geophysics, and geochemistry of these sites, important clues to the value of the geothermal resource will be uncovered.

Studies should include:

- Geothermometry/Geochemistry – Evaluations of geothermal spring and well geochemistry should be done in key areas to estimate the reservoir temperatures at depth. In areas where this has been done in the past, an evaluation of the data should be done to determine if any new geothermometry methods could help constrain ambiguous results.

- Remote Sensing – Hidden geothermal systems can leave clues to their presence through trace minerals at the surface of the Earth. These can be identified and located through remote sensing techniques (especially hyperspectral imagery).
- Field Data Collection – The best way to help confirm or deny geothermal resource potential is to maintain a consistent effort of field data collection, including:
  - Geologic Mapping – this is necessary in areas where mapping on a detailed scale (at least 1:24,000) has not been done;
  - Geophysical Surveys – including gravity, resistivity, seismic surveys;
  - Geothermal Test Holes – these shallow wells are drilled to gain data on the heat flow and geothermal gradient of the area;
  - Slim Holes – these are smaller diameter, but relatively deep drill holes to test potential reservoirs. These provide data on temperatures, porosity and permeability of the reservoir at depth.

These studies should initially commence on the most prospective areas identified in the "Current Geothermal Resource Characterization" section above. Those resource areas should be ranked in priority order based on a matrix of geothermal evidence factors and studies then proceed in priority order.

1.4 BARRIERS TO DEVELOPMENT

Recent legislative incentives, such as federal production tax credits and the Colorado renewable portfolio standard have helped improve the environment for geothermal resource development. Still, there are a few barriers that hinder development.

As mentioned above, funding for exploration of geothermal resources is minimal on the federal level. Until recently that has also been the case at the state level, however in 2007 Colorado created the Colorado Renewable Energy Authority and a Clean Energy Fund, portions of which can be used to support geothermal research.

Because many geothermal resources involve federal land, leasing rules have been a barrier to development. There is currently a 20-year backlog of federal geothermal lease applications in many western states. This is not the case in Colorado, however, because there have been very few new geothermal lease applications in recent years. That situation may change soon, so it is important to streamline the federal leasing rules to achieve timely decisions on lease applications. The Bureau of Land Management (including National Forest System lands) is beginning to address this issue through the recent promulgation of new leasing rules, published in June 2007 and the commencement of a Programmatic Environmental Impact Statement (PEIS) on geothermal resource development in July 2007. The PEIS process is scheduled to be complete in late summer 2008. Input from interested parties is encouraged throughout this process.

Finally, the potential for conflict with existing geothermal resource users can discourage additional development of the resource, whether for direct use purposes or electrical power generation. Many of the thermal springs and wells in Colorado are currently being used in direct applications such as recreation pools and spas, aquaculture, greenhouses, and heating of building structures. These entities have a vested interest in maintaining their current use of geothermal waters. A delineation of the legal framework for resolving resource conflict issues could help maximize the beneficial use of the geothermal resources and allow a developer to quantify the risk involved in potential conflicts.

1.5 CONCLUSION

Colorado's potential for electrical power generation from geothermal resources is prospective, but not yet proven. Several areas of the state should be investigated further to prove their resource value. These locations include the Mt. Princeton area near Buena Vista, the Waunita Hot Springs area in southeastern Gunnison County, the San Luis Basin especially along its margins, the San Juan Mountains near Ouray and Rico, Pagosa Springs, the Raton Basin west of Trinidad, the Steamboat Springs area, and possibly an area near Somerset.

Many, but not all, of the known geothermal springs and wells are currently being put to use by direct transfer of the heat energy for recreation, agriculture, or space heating. Additional opportunities for direct use of geothermal resources exist, but capital expenditure for drilling wells may be necessary. Continued geothermal resource investigations and their findings will be helpful in expanding direct use applications.

Continued research and investigation of the geologic framework of Colorado's geothermal resources is necessary to minimize uncertainty about the resource and maximize responsible development. Colorado has a good base of geothermal information from past research. Recent studies by the Colorado Geological Survey and the Massachusetts Institute of Technology provide more evidence of the state's geothermal potential. Additional characterization and feasibility studies are warranted to encourage commercial development of this clean renewable energy resource.

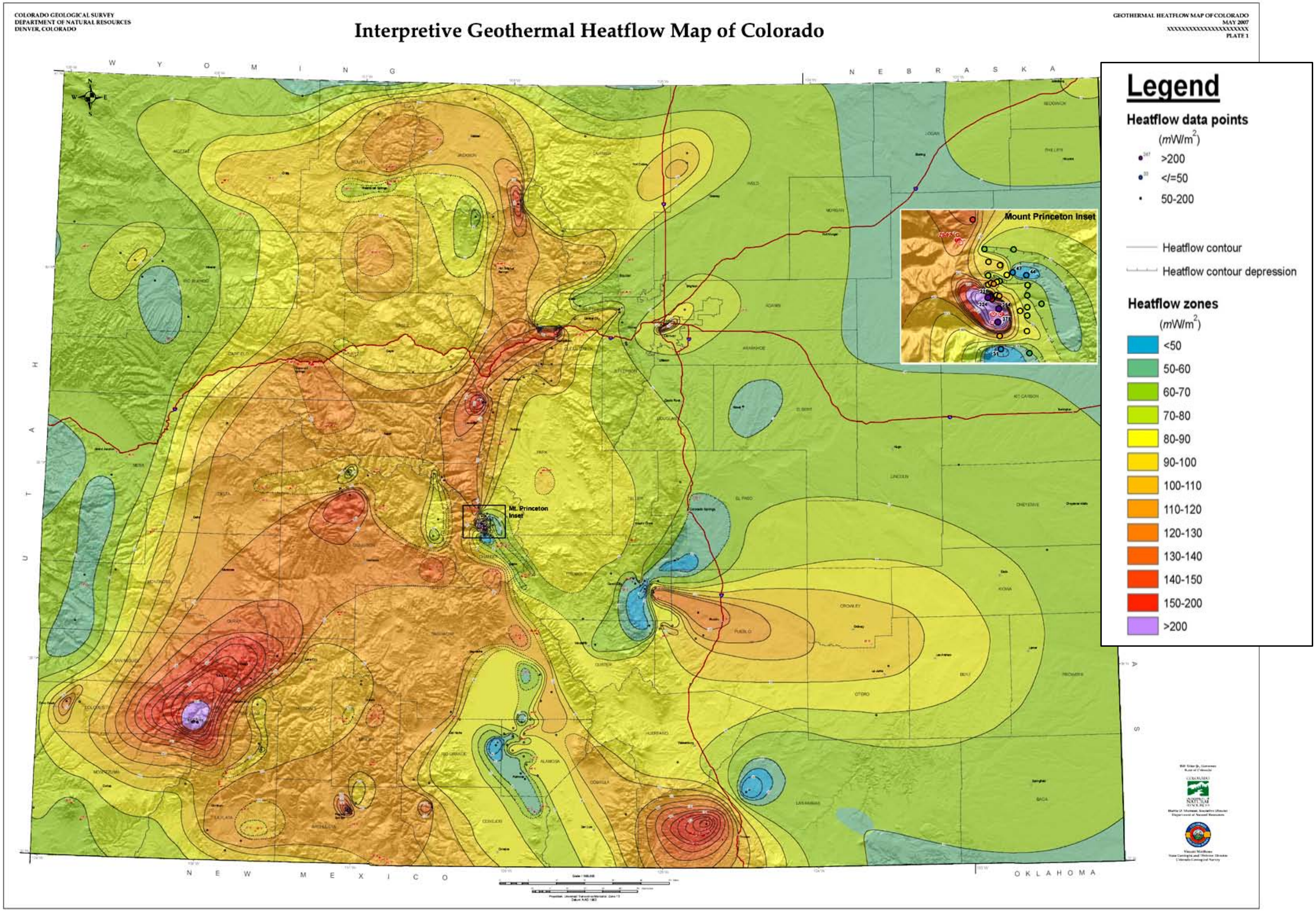

Figure 1. – Draft Interpretive Geothermal Heat Flow Map of Colorado

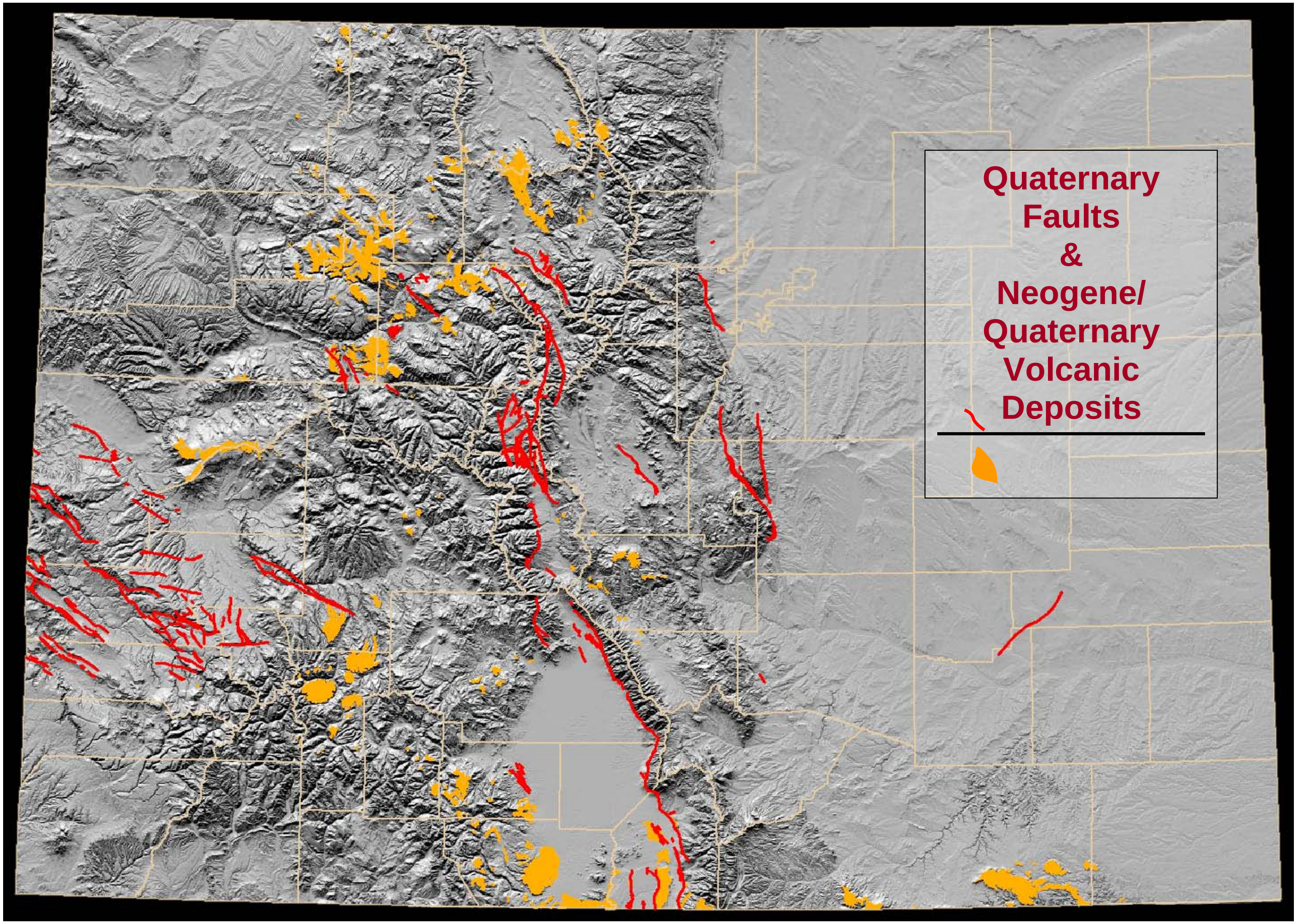

Figure 2. – Quaternary Faulting (<2 million years) and Quaternary-Neogene Volcanism (<23 million years) in Colorado.

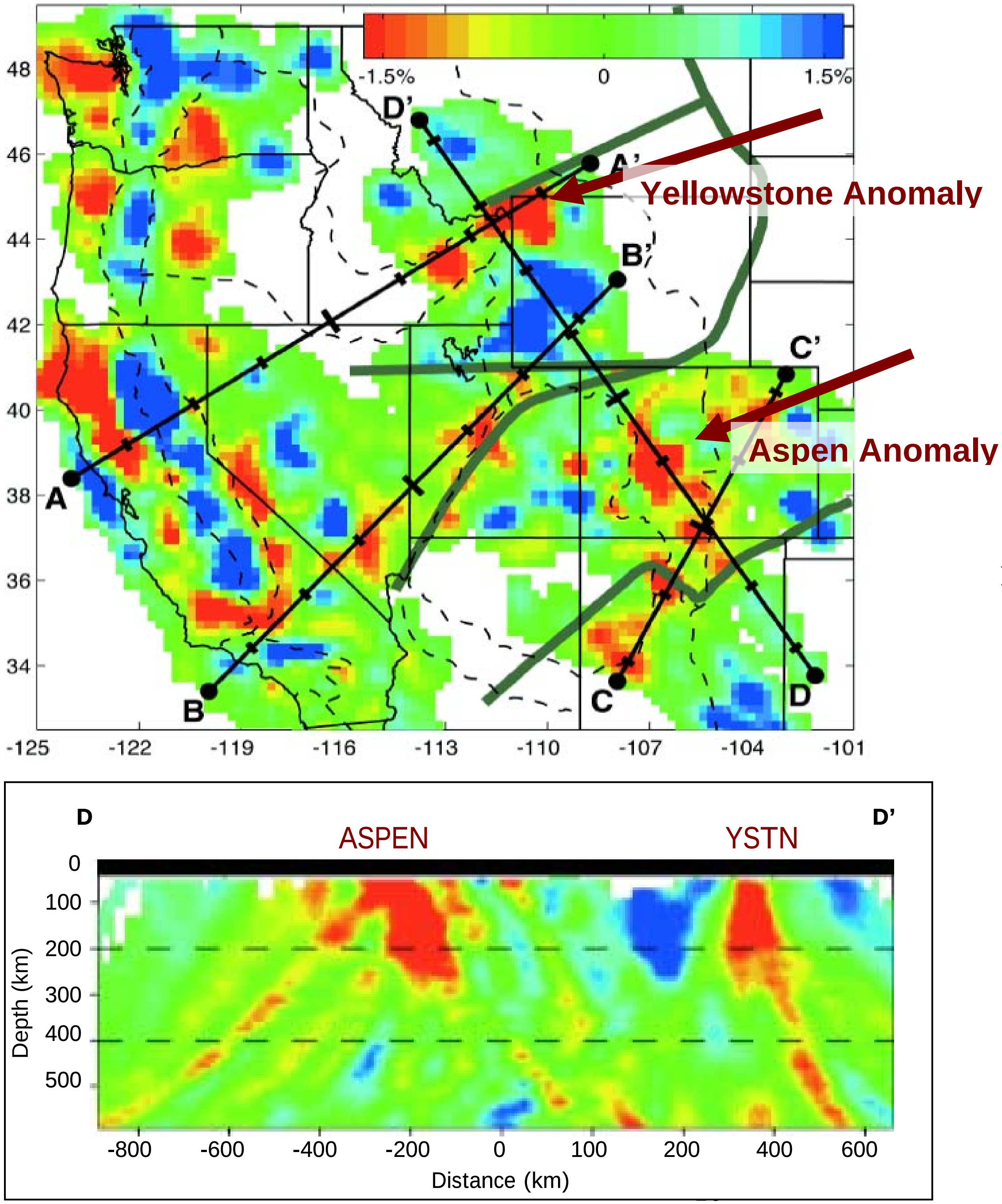

Figure 3. – Tomographic P-wave velocity map and cross-section, western U.S. (*from* Dueker, Yuan, & Zurek, 2001)

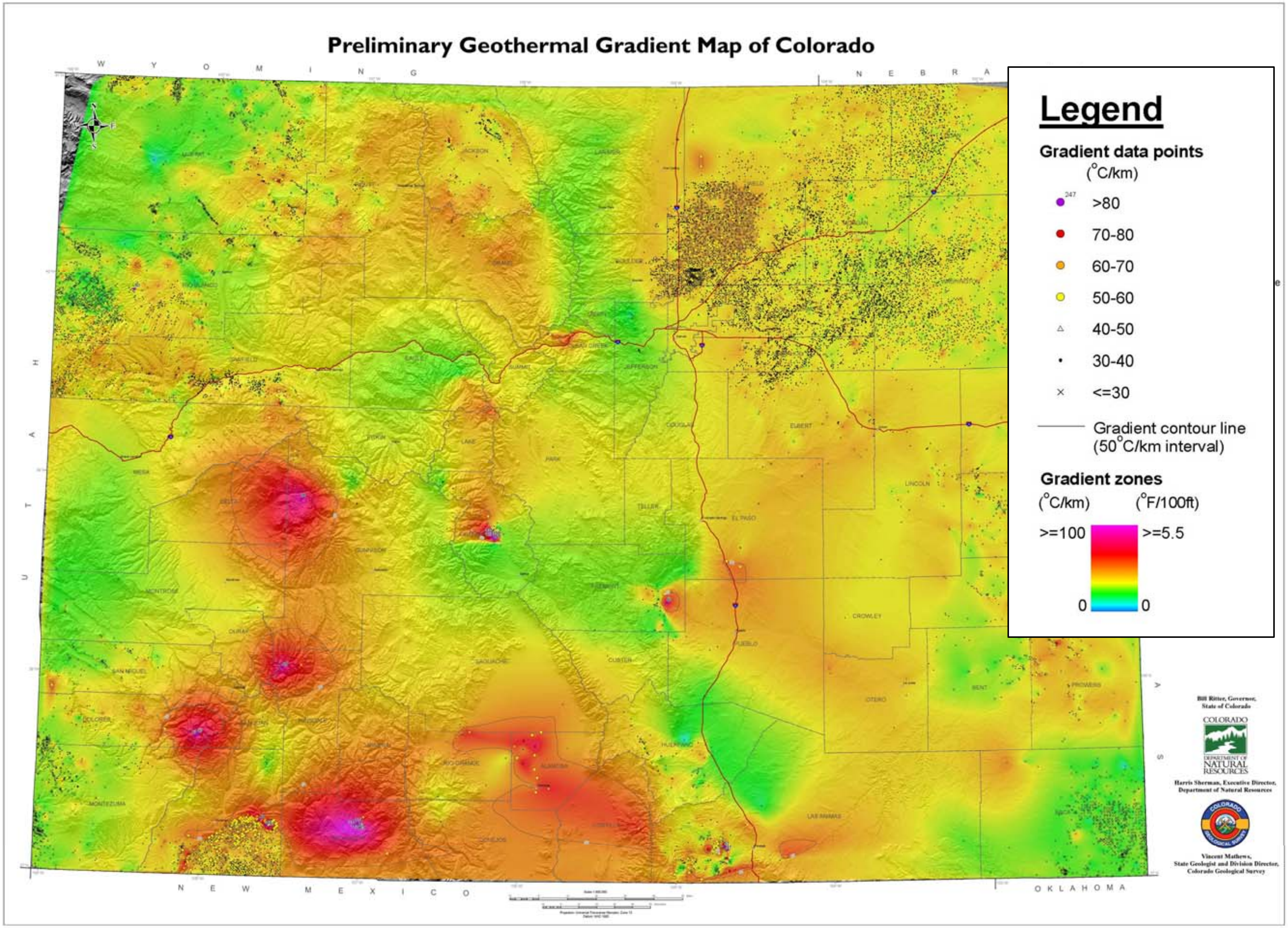

Figure 4. – Preliminary Geothermal Gradient Map of Colorado

APPENDIX B

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[1] Tester and others, 2006, Appendix A, Table A.2.1.

2.0 DIRECT USE DEVELOPMENT

BACKGROUND

"Direct use" means either using the geothermal water itself as the end application (as in a swimming pool, or a fish farm), or using the heat from geothermal water to directly heat one structure, multiple structures (district heating), commercial greenhouses, food processing facilities, or an industrial process. Direct use applications can use medium-temperature geothermal water (from about 65°F to 175°F) as the heat source, or it can use the low-temperature, ambient shallow ground temperature in a heat-pump exchange.

Present medium-temperature direct use applications are concentrated in south-central and southwestern Colorado, with a few in the central mountains (Figure. 1).

Direct Use applications (DU) of geothermal energy in homes and commercial/industrial operations can be much less expensive than using traditional fuels, with savings as high as 80 percent over fossil fuels. Geothermal direct use is also very clean, producing only a small percentage (and in most cases none) of the air pollutants emitted by burning fossil fuels.

In Colorado, there are 36 known direct use projects currently in operation, which are dominated by pools and spas (21) and direct space heating projects (10), with a few aquaculture facilities. A number of additional projects (including greenhouse, community pool, and district heating applications) are currently being considered due to the cost-competitive business advantage geothermal provides over conventional fuel sources.

Direct Use systems typically include three components:

- A production facility, usually a well, to bring the hot water to the surface;
- A mechanical system – piping, heat exchanger, controls – to deliver the heat to the space or process; and
- A disposal system – injection well or storage pond (in most cases, an injection well is required) – to receive the cooled geothermal fluid.

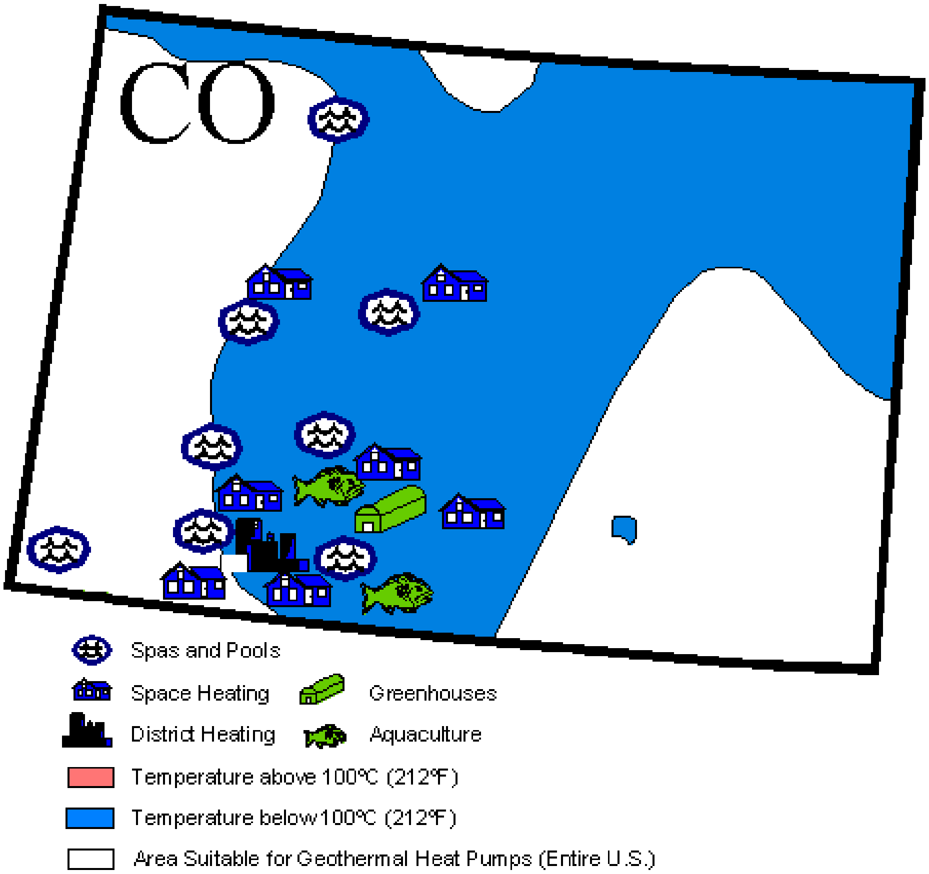

Figure 1. Map of Colorado Direct Use Projects (Source: http://geoheat.oit.edu/state/co/co.htm).

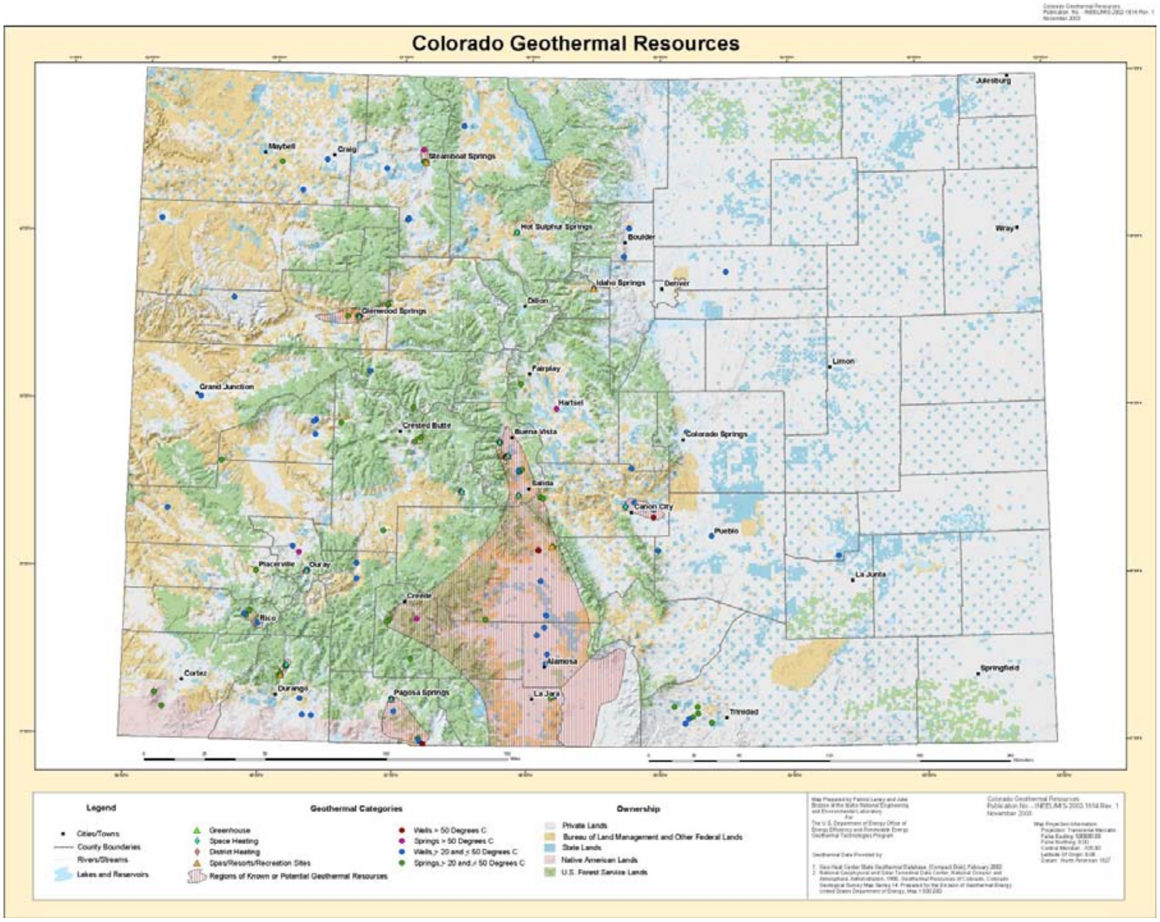

Figure 2. Geothermal Resource Map of Colorado (INEEL, 2003).

BARRIERS TO DIRECT USE PROJECTS

2.1 Resource-Related Barriers

- *Location of Resources Not Known Well Enough To Design New Projects*
  Low-temperature geothermal regions are only defined on the 1:500,000-scale map of Colorado (Figure. 2). The boundaries of the resource areas are insufficiently precise at this scale for commercial development and would require an exploration phase.

- *Temperature-Depth Trends Not Known Well Enough to Design New Projects*
  Within each low-temperature geothermal region, only a general temperature-depth trend is known, but where data are more abundant (e.g., San Luis Valley), it is clear that temperature-depth trends vary spatially within the region, often significantly. These variations span the cutoff values for economic viability for a project.

- *Transmissivity and Yield Not Known Well Enough to Design New Projects*
  Having high subsurface temperature is not enough to guarantee a successful project. If the yield of warm water is too low within each low-temperature geothermal region, only

a general transmissivity is known, but where data are more abundant (e.g., San Luis Valley), it is clear that transmissivitiy varies spatially within the region, often significantly. These variations span the cutoff values for economic viability for a project.

- *Use of "Inherited" Geothermal Sources*
  Many direct-use operations in the San Luis Valley and elsewhere derive their geothermal water from wells that were drilled decades ago for purposes unrelated to today's geothermal utilization project. Therefore, today's geothermal operation did not pay for drilling the well. As a result, its income stream does not have to service a debt for drilling the well, so the hot water is in essence "free." This situation will not exist for any new geothermal project, so it is unknown whether a new direct-use project can be economically viable.

2.2 TECHNOLOGY-RELATED BARRIERS

- *Cost of Resource Measurement*
  The high cost of drilling small-diameter exploration holes to measure transmissivity and temperatures of the target zone discourages exploration. Because there is no such existing technology specific to small-diameter exploration, the current cost of drilling a geothermal exploration well is identical to that of a geothermal production well, about $129/ft for a 3,400 ft-deep well, and $250,000 for a 1,200 ft-deep well.

- *Cost of Drilling*
  With present drilling technology, the costs of drilling the production and reinjection wells (if required) represents up to 95 percent of the costs of a small project, and 70 percent of a medium-size project. This cost is too high, and will result in most small direct use projects being uneconomic.

- *Lack of Utility Experience with Direct Use Projects as a Business Strategy*
  Direct use projects utilize thermal energy (BTUs) onsite to provide heat to buildings, processes, and other end-use needs. These projects are usually implemented on the customer or demand-side of the utility meter. While utilities supply customers with natural gas (BTUs) and/or electric energy (kWh) through pipelines and distribution lines, there is very little domestic utility experience with selling customers BTUs from localized geothermal resources via direct use applications.

  Therefore, a critical barrier to utility involvement in geothermal direct use activities is lack of experience in designing and financing geothermal direct use projects and determining appropriate methods of cost recovery. Utility cost recovery and revenue stream generation could be accomplished through a number of mechanisms including direct sales of BTUs, low-interest loans, utility energy savings contracts, or lease back programs.

2.3 PROGRAMMATIC BARRIERS

- *Government Funding Lacking for Exploration Phase*
  All geothermal projects consist of two phases - exploration and production. Currently available incentives (e.g., USDA Farm Bill, Section 9006) are for the development phase only, leaving developers without financial assistance in the expensive exploration phase. As a result, developers may skimp on exploration. This approach jeopardizes the entire project, which could result in drilling a cold or dry hole.

- *Regulations of Colorado Division of Water (DWR) Resources Hamper Development*
  Due to over appropriation of the confined aquifer in the San Luis Valley, DWR does not allow surface disposal of geothermal fluids augmentation. Essentially this means that all new projects will have to include two deep wells: a production well and a re-injection well, even for shallow and warm direct use applications.

  - DWR regulations are unformulated concerning the depth to which geothermal spent fluids must be re-injected. Because the cost of the re-injection well is a big project component, economic feasibility of projects cannot be accurately assessed prior to drilling

  - DWR regulations for drilling Type A and Type B geothermal wells require information that will not be known until after the well is drilled. Therefore, an initial exploration well may be necessary, in addition to the production and re-injection wells. This requirement for three wells for a single direct use project increases project cost relative to benefits and will probably make all new direct use projects uneconomic.

OPPORTUNITIES FOR DIRECT-USE PROJECTS

2.4 Resource Related Opportunities

- *Large Potential Resources*
  The San Luis Valley is a large, diffuse area of geothermal water ranging from low temperature at intermediate depths (2,000-4,000 ft) to above-boiling temperatures at deep depths (7,000-9,500 ft). Existing direct-use projects (swimming/spas, greenhouses, aquaculture, commercial space heating, residential space heating) indicate that temperatures at 2,000-4,000 ft are sufficient for these uses, and water quality is OK. There is a huge potential for more direct-use projects, if barriers can be overcome.

- *Other Geographic Areas*
  Much shallower hot water may be present on the fringes of existing KGRAs, such as Mineral Hot Springs (San Luis Valley), Pagosa Springs, and other areas of southwestern and central Colorado. In those areas, the main task will be to perform sufficient hydrogeological characterization of the geothermal system, that we can assure that future development on the margins will not negatively affect existing commercial geothermal projects.

2.5 Technology Related Opportunities

- *Growing Markets*
  If a Colorado firm could develop the technology to help overcome any of the barriers described above, they would be able to market that technology to fast-growing national and international markets.

2.6 Programmatic Opportunities

- *Improving Local Economy*
  Development of direct-use projects can be part of a robust economic development strategy with numerous benefits provided to the community and the utility. Development of direct-use projects provides community benefits through job creation, diversification of the local economy, and an increased tax base. Utilities benefit by promoting fuel switching away from volatile priced natural gas and propane fuels to stable priced geothermal BTUs. In addition, sales of geothermal BTUs to customers would result in increased revenues to the utility. Selling BTUs to customers could be accomplished in a seamless manner via the use of simple BTU meters and an additional line item on monthly utility bills.

- *Earning Renewable Energy Credits*
  The second area of opportunity for utilities to enter the direct use market is as an RPS compliance strategy, or to generate Renewable Energy Credits (REC) for use in environmental programs or sales into RPS or other REC markets. Use of thermal RECs for RPS compliance or sales into RECs markets can significantly increase the value of utility-owned direct-use projects. Currently, there are three states in the U.S. that allow thermal energy to count toward RPS compliance. Colorado is not one of them, but the opportunity exists to change this in the near future.

- *Funding Exploration*
  Financial assistance for developers in the exploration development stages would pay dividends immediately because it would spur the completion of projects; completed projects are necessary to demonstrate proof-of-viability for new direct-use projects in Colorado, which include the costs of new geothermal wells.

ACTION ITEMS FOR DIRECT USE PROJECTS IN COLORADO

2.7 Resource Related Action Items

- *Fund Continuing/New Resource Research*
  Create funding mechanisms for research into the subsurface geology and hydrology of known geothermal regions in Colorado, focusing on temperature-depth, transmissivity patterns, and water quality of geothermal waters (which controls re-injection depths).

Solicit proposals from Colorado Geological Survey, universities and private contractors to conduct the studies.

2.8 Technology Related Action Items

- *Fund Technology Development*
    - Fund research into cheaper well-drilling methods, especially for small-diameter holes for the exploration phase; these wells only need to be large enough for a temperature probe and geophysical surveys (a few inches in diameter).

    - Fund research into surface geophysical methods that can potentially estimate transmissivities and temperatures at the depths of production targets (3,500-10,000 ft).

    - Fund research into developing a deep, closed-loop geothermal well system, where re-circulating fluid is heated at the bottom of the loop, brought to the surface, run through a heat exchanger, and re-circulated to the bottom of the loop. This would be the same type of closed-loop technology currently used in shallow heat pump applications, but extending to depths of 3,500-10,000 ft. A closed loop system would avoid the regulatory restrictions such as those applied by DWR in over-appropriated groundwater basins, including the San Luis Valley.

2.9 Programmatic Action Items

- *Exploration Funding*
  Create a state funding program to partially support geothermal exploration; could be a matching fund, grant/loan program such as the USDA 9006 program.

- Revise DWR regulations to ease the permit process for geothermal drilling.

3.0 GEOTHERMAL HEAT PUMP DEVELOPMENT

BACKGROUND

Geothermal heat pumps (GHPs) are the most energy-efficient, environmentally clean, and cost-effective space conditioning system available, according to the U.S. Environmental Protection Agency. In fact, GPH save nearly 6,000 pounds of CO2 emissions annually compared to the standard American home with central air conditioning.[ϕ]

GHPs, also known as ground source heat pumps, circulate liquid, usually water, through loops buried in the ground, utilizing the earth alternately as heat source and sink to warm buildings during winter months and cool them during summer months.

There are many types of GHPs with most variations found in the layout and matrix of thermal exchange tubes located underground. *Closed Loop Systems* utilize and recycles the same fluid over and over again. There are two main types of closed loop systems: horizontal and vertical. Horizontal loop systems extend horizontally to the surface of the earth and are usually placed at a depth of 3 to 6 feet below the surface. Depending on the amount of heat needed for the building, an appropriate amount of tubing is laid down in the ground. Vertical loop systems extend vertically from the surface of the earth and can be up to 300 feet into the ground.[‡] Using "slinky" style tubes in vertical systems can decrease the requisite depth of the system by up to two thirds.

GHPs can also use local bodies of water or underground aquifers instead of ground heat transfer. These can be both open or closed loop. *Open Loop Systems* operate similarly to the closed loop systems but the liquid utilized in the heat transfer system is taken from an outside source and not reused.

Benefiting from the relatively constant temperature of the earth, GHPs use significantly less electricity than conventional heating or cooling systems.[§] In addition to resulting in reduced energy bills, GHPs are quieter, less costly to operate and produce far less emissions than conventional HVAC systems. The extent of savings on operating costs from implementing GHPs, however, depends on whether the switch is from electricity, oil or natural gas.

While GHPs can reduce energy use by over 70 percent when replacing electric resistance heating, displacing a natural gas or propane heater with GHP actually increases the consumption of electricity (the compressor and pump require electricity to move heat to and from the ground). Such replacements are, therefore, best suited to areas with moderate electricity rates. Colorado is well suited since its electricity rates are in the moderate range (as of January 2007, Colorado electricity rate of 7.72 cents/kWh was below nation's average of 8.72 cents/kWh).[**]

[ϕ] Geothermal Heat Pump Consortium, http://www.geoexchange.org/pdf/california.pdf

[‡] Geothermal Heat Pump Consortium, Geoexchange, http://wwww.geoexchange.org/about/how/htm accessed on 6/11/07

[§] GeoExchange Heating and Cooling Systems: Fascinating Facts, US DOE, EERE, Geothermal Technologies Program (http://www.geoexchange.org/documents/GB-003.pdf)

[**] Electricity Rate Comparison by State – Official Nebraska Government Website http://www.neo.ne.gov/statshtml/115.htm

GHP technology can lower the strain on an already burdened grid. Although electricity is used to power the pumps and compressors on these systems, the load needed is rather steady. It does not have the variable high and low load requirements that exist with traditional electric heating and cooling units. Load variability requires many utilities to invest in expensive reserve power systems. Investing in steady load base GHP systems will help lessen load variability and improve the efficiency of the electric grid.

As of now, at least a dozen or more public buildings throughout the state of Colorado use GHPs for heating and cooling. Additionally, the state has seen a surge in installation of GHPs at residences in its western region thanks to the active promotion of the Delta-Montrose Electric Association (DMEA).[††] However, wider implementation of GHPs is still constrained by a number of barriers.

3.1 Current Barriers for Wider GHP Implementation

- *High Installation Cost*
  The largest barrier to increased usage of GHPs for consumers is its high cost of installation. GHP installation costs vary from region to region depending on availability of materials and expertise of contractors. Typically, a GHP system installation may entail a premium of 20 percent to more than 100 percent compared to conventional air-source systems of the same heating/cooling capacity. These high costs stem from the investment in properly designing and installing the ground loop systems.

  Although installation is cost intensive the payback period for GHPs is estimated to be from two to 10 years given their low maintenance and operational costs.[‡‡] The payback varies based on construction costs, heating/cooling capacity, and the cost of competing sources of energy (electricity, natural gas, propane).

  Currently, the applicable federal and state incentives for GHPs are as follows:[§§]
  - Residential Energy Efficiency Tax Credit: Established under the Energy Policy Act of 2005, this incentive program provides personal tax credits – 100 percent on installation of a new GHP with a cap of $300. The credit is applicable for equipment placed in service by Dec 31, 2007.

  - USDA Renewable Energy Systems and Energy Efficiency Improvements Program: Section 9006 of the 2002 Farm Bill requires USDA to award grants of up to 25 percent of the projected cost of technology implementation, and guarantee loans to agricultural and rural businesses for implementation of

[††] http://www.nrel.gov/docs/fy06osti/38241.pdf
[‡‡] Analysis of Geothermal Heat Pump Manufacturers Survey Data by Peter Holihan, http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/html/geotsurv.html#geoecon
[§§] Database of State Incentives for Renewables and Efficiency (http://www.dsireusa.org/index.cfm?EE=1&RE=1)

renewable energy technologies, including GHPs. Grants are capped at $500,000 for renewable energy projects, while loans are ensured up to 50 percent, with a limit at $10 million. The bill is due to expire at the end of FY 2007.

  - Residential Co-Z Energy Loan Program: The only utility loan program in Colorado for GHPs is administered by Delta-Montrose Electric Association (DMEA), a distribution utility serving western Colorado. Under the "Co-Z" plan, DMEA pays all up-front cost for installation of GHP-related equipment external to a home. Over time, the cost is recovered by DMEA through monthly payments applied to the utility bill. DMEA provides a one-stop-shop for GHPs by performing energy analysis of the home, customizing system design, and providing complete comparison of current energy use, cost of installation, and savings accrued over time. DMEA is also piloting a loop tariff to provide a fixed monthly charge for the use of a utility-owned heat pump loop. These resources are available to DMEA customers only.

- *Lack of Awareness*
  A significant number of consumers are unaware of the benefits of GHP-based HVAC systems. Also, GHPs are still regarded as an "innovation" and are generally associated with a high degree of risk although they have been in commercial operation for over 30 years with proven reliability. This in turn translates into lack of wider acceptance of the technology, preventing it from being a mainstream option.

- *Lack of Uniform Standards*
  The GHP design and installation expertise has yet to receive nationally standardized accreditation. The International Ground Source Heat Pump Association (IGSHPA), in partnership with the Geothermal Heat Pump Consortium and the Association of Energy Engineers, does offer a certified training course in GHP design, installation and maintenance.[***]To date, the certificate is only recognized in 10 states as a standard for expertise in ground loop heat exchange, Colorado not being one of them. This means that opting for GHP installation involves risk-taking for utilities and makes them vulnerable to liability issues under adverse conditions. Recognition of the certificate in Colorado will foster trust and reliability in GHP system installations and long-term services, spurring wider implementation.

- *Shortage of Trained Installers*
  Finally, a trained workforce is necessary to enable assessments, GHP installations, troubleshooting and maintenance. Architects and design engineers must be trained to evaluate the potential for GHPs in new commercial and residential buildings, make comparative analyses, and must have trained installers at hand to ensure smooth installation. By having professional standards and certified installers, the risks of installing GHPs will be minimized. Also, easily available trained technical service providers from coast to coast will earn trust in the technology and encourage its popularity nationwide.

[***] International Ground Source Heat Pump Association (http://www..igshpa.okstate.edu/training/accredited.htm)

3.2 Opportunities for Installing GHPs

- *Savings on Energy Bills*
  Building of new houses, schools, and commercial buildings offers an ideal opportunity for installation of geothermal heat pumps; GHPs can be installed anywhere in the country. While residential installations entail higher costs than conventional HVACs, the costs for installing state-of-the-art GHP systems in commercial buildings are competitive with that of boilers and cooling towers. In the case of new homes, the cost of a GHP installation could be added to homeowners' monthly mortgage payments; the excess amount will be easily offset by monthly savings on energy bills. Even as retrofits, the high efficiency of the GHP systems mean lower energy bills, allowing investments to be recovered within two to 10 years.

- *DMEA's Co-Z Energy Plan*
  DMEA's Co-Z initiative is an excellent opportunity for its members. It is an integrated program that reduces the burden of installation costs and ensures reliable customer service for GHP maintenance and operation. The service is ideally suited for houses that are over 1,500 sq. ft. or built on at least an acre of land. The Co-Z program helps by custom designing the system, building the outdoor portions of the system, offering energy credits, and locking in electricity rates for a determined interval of years. Adoption of this program by other state utilities would provide an attractive financial option for customers, which would help drive demand.

3.3 Actions for Installing GHPs

- *Develop Incentive Packages/Financing Options for GHPs*
  The up front cost of installing ground loop systems is a major barrier to the acceptance of GHP technology by utilities, even though it offers reduced energy bills and requires a low amount of maintenance. State policies could play a major role in reducing this barrier as they affect utility markets, production costs, preferences for alternatives, and other factors relevant to technology development. The value of robust financing assistance plans for GHP installations is a proven and successful implementation strategy. 26 states currently offer incentive programs that have resulted in significant increases in GHP installations.

  With the recent signing of HB-1037, utilities can now take advantage of financial incentives for offering assistance with demand side management technologies, including geothermal heat pumps.

  The Colorado State Working Group (CO-SWG) and the GPW Utility Geothermal Working Group (UGWG) should jointly address the following issues to stimulate the GHP market:
    - The "Co-Z" plan offered by DMEA has been a very successful program. The CO-SWG can be active through its partnership with UGWG in exploring how to get

other organizations in the state to replicate the efforts or build off the success of the Co-Z plan.
- CO-SWG and UGWG should consider laying out a financial roadmap for utilities detailing financing options, impacts on load shapes and cost structures, and payback periods for customers with GHP installations.
- Encourage investor owned utilities to incorporate GPHs into their demand side management plans under HB-1037.

- *Implement Recognition of GHP Technology Standards and Certified Installers*

A regulatory framework that attests to the design and installation of ground loop systems will encourage interest of utilities in the technology. The following action items will be pursued to standardize GHP installations in Colorado:

- Working toward state accreditation of the joint International Ground Source Heat Pump Association and Association of Energy Engineers' Certified GeoExchange Designer course.
- Encouraging the use of professionally certified GeoExchange Designers by publishing articles about the benefits of guaranteed proficiency and experience in appropriate media for home builders, design engineers, and architects.
- Providing informational training through professional associations of architects, design engineers, and homebuilders on the benefits of GHPs and certified installations.

4.0 GEOTHERMAL ELECTRICITY PRODUCTION

BACKGROUND

Although Colorado has abundant geothermal resources in certain regions that could support electricity production in an economically viable manner, there are currently no geothermal power plants in the state. While Colorado has the fourth highest geothermal heat flow of any state in the country, its temperatures are in the low to moderate range; these temperatures can typically support only one type of geothermal power generation technology known as a *binary cycle power plant.*[*]

There are generally three types of geothermal power generation technologies. The first and oldest technology is the *dry steam plant* which utilizes geothermal fluids that are primarily steam. This steam is piped directly to a turbine that drives a generator that produces electricity. Utilizing geothermal steam in the turbine eliminates the need for burning fossil fuels in the plant, and the resulting emissions are only excess steam and insignificant amount of gases.

The second type of geothermal power plant is a *flash steam plant* which is employed when geothermal fluids above 360°F are available. In a flash steam plant, the fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or “flash”. This vapor then drives a turbine, which drives an electricity generator. If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy.

The third type of geothermal power plant is a *binary cycle plant* which is typically utilized for moderate temperature geothermal resources (below 350°F). In a binary cycle plant, the geothermal fluid is passed through a heat exchanger along with a secondary working fluid that has a much lower boiling temperature than water. The heat transferred from the geothermal fluid causes the secondary fluid (typically iso-pentane or a refrigerant) to flash to vapor. The vapor then drives a turbine and generator. Binary systems are closed loop systems, and as such have virtually no emissions.

Moderate-temperature geothermal resources are by far the most common. With the combination of higher resource availability and recent advances in the technology, binary cycle plants will likely see increased market penetration as they open up new markets with geothermal resources previously thought to be too low in temperature to support power generation.

In Colorado, the consensus among resource experts suggests that only the binary cycle power plant is applicable to resources in the state. The key to successful binary power plant applications is to maximize the temperature difference, also called the “delta T”, between the geothermal resource and the cooling water. Based on the existing geothermal resource maps, it appears that the High Country, the Front Range and the Western Slope (within areas known as KGRAs) have

[*] United Technologies Corporation demonstrated the technology successfully at Chena Geothermal Power Plant in Alaska, using the lowest-temperature geothermal resources for commercial power production in the world.

the highest potential for binary power generation because they have adequate geothermal resources as well as cold mountain streams to increase the temperature differential of the system. While no binary power plants have been built in Colorado, a number are under consideration, and it is thought that binary power generation may be able to utilize geothermal temperatures as low as 175°F in certain areas of the state.

4.1 BARRIERS TO UTILITY GEOTHERMAL POWER DEVELOPMENT

- *High Cost and Risk of Exploratory Drilling*
  Drilling of exploratory wells, even in areas of known geothermal resources, is an expensive component of developing a geothermal power project; it can also be highly risk prone. Even with intensive geological investigations conducted prior to drilling, drilling a dry hole is always a risk. However by focusing on the completion of current mapping undertaken by the Colorado Geological Survey, drilling risk can be lessened.

  The cost of drilling is a direct function of the depth of drilling. As an exploratory hole is drilled deeper, there is no exact science for determining whether the chances of hitting the geothermal resource are greater by continuing to drill deeper or to abandon the hole and start drilling a new exploratory hole at the site. As a result, exploratory drilling entails both monetary and technical risk. While some areas certainly have less risk than others, particularly areas with more abundant drilling data, the risk of exploratory drilling is unavoidable. Alternatively, with proper geological investigation and experienced drillers, these risks can be reduced, and the economic benefits of hitting the resource at the location and depths expected can increase.

- *Lack of Understanding of the Total Value-Added Benefits of Geothermal Power*
  Many utilities do not fully appreciate the full value-added benefits of geothermal power, or its role in the utility resource mix. Geothermal power is a clean, reliable, and stable-priced source of base load electricity. One of the barriers to increased geothermal power development in Colorado, as in many other states with an RPS, is that RPS requirements[†] are energy or kWh-based and do not reflect the resource needs of utilities in terms of kW or capacity. Thus, utilities pursuing renewable resources to comply with RPS requirements or voluntary greenhouse gas reduction programs generally acquire the lowest cost energy resources with no consideration to capacity values. Wind energy is usually the renewable resource of choice in such circumstances. However, wind is an intermittent resource, and while it certainly fills a need in utility resource portfolios, many utilities in Colorado are seeking additional base load power resources – a need that can be filled by cost-competitive geothermal power that operates with a more than 90 percent annual capacity factor. Utilities need to become increasingly aware of the value-added benefits that can be provided by geothermal power in Colorado.

- *Timely Permitting by Federal Agencies*

[†] Renewable Portfolio Standards (RPS) establish requirements for electric utilities and other retail electric providers to serve a specified minimum percentage (or absolute amount) of customer load with eligible sources of renewable electricity.

Most high potential geothermal resources lie within the vast stretches of land controlled by the National Forest Service (NFS) and Bureau of Land Management (BLM). As with oil, gas, and other mineral resources, a timely permit process is crucial in reducing risk and allowing developers to take advantage of the current production tax credit. The BLM and NFS are preparing a joint Programmatic Environmental Impact Statement (PEIS) to analyze and expedite the leasing of BLM-and NFS-administered lands with high potential for renewable geothermal resources in 11 western states and Alaska.

Geothermal leasing is currently permitted on Interior and other federal lands that are designated for this type of development. The BLM currently administers about 420 geothermal leases; 55 of those are producing geothermal energy, including 34 power plants**.** The BLM has been expediting the application process for geothermal leases, issuing 291 leases since 2001, compared to 25 leases from 1996-2001.

The PEIS will also analyze the steps necessary to facilitate the processing of the approximately 100 geothermal lease applications that were pending as of January 1, 2005, as mandated by the Energy Policy of Act of 2005. The law stipulated that 90 percent of these applications must be issued, rejected, or otherwise disposed of by August 8, 2010.

4.3 OPPORTUNITIES FOR UTILITY GEOTHERMAL POWER DEVELOPMENT

There are a number of factors in Colorado that currently point to increased opportunities for geothermal power generation by utilities.

- *Compliance with RPS Requirements*
  For the regulated investor-owned utilities and the rural electric cooperatives falling under the Amendment 37 RPS requirements, recognizing the role of geothermal power as a base load resource is a compelling opportunity. Through this opportunity, not only does geothermal power assist in RPS compliance, but it also provides environmentally sound and stable-priced base load power capacity additions to a utility's resource portfolio.

- *Alternative to More Coal Plants*
  Another factor that provides an opportunity for geothermal power development is the fact that a number of rural electric cooperatives in the western states, including one in Colorado, are not extending their power supply contracts with their long-term wholesale power suppliers. While the majority of these contracts do not expire any time soon, these cooperatives have stated that the reason for not renewing their power supply contracts is that they don't want suppliers building coal plants on their behalf, nor do they want to pay for any new coal plants.

  There are a number of reasons for not wanting any new coal plants, including the potential for a future carbon tax that would increase coal fired electricity prices, environmental concerns and liability, and potential volatility of future coal prices.

Geothermal power, while it certainly couldn't come close to replacing all of the new proposed coal-fired electricity needs in Colorado, could play a role in bridging the gap for new base load resources at stable and cost-efficient prices. In addition, geothermal can provide a hedge to utilities against other base load resources, since a properly designed geothermal power system won't deplete the underlying resource and can maintain power production costs at near-fixed levels over the long-term.

- *Easing Over-stressed Electrical Distribution Systems*
  Many utilities in Colorado are experiencing load growth that is over-stressing their power distribution system. Geothermal power production, as a distributed generation (DG) resource, can play a role in easing the burden on over-stressed distribution systems. One of the benefits of the binary power systems that are applicable in Colorado is that they are highly scalable and can range in size from 200 kW to over 30 MW. As a result, they can be sized to the needs of the utility's requirements (assuming there is an underlying geothermal resource to support it), and provide a number of functions within utility service areas. Geothermal power, when utilized as a DG resource, can provide voltage support and power supply at the end of long radial feeder lines, provide VARS back to the system, and support other utility ancillary services such as contribution to spinning reserve requirements.

4.4 ACTION ITEMS

Aligning the Colorado State Working Group's efforts with those of the Utility Geothermal Working Group (UGWG) will allow the geothermal implementation issues to be addressed more effectively. The following action items are recommended:

- *Form a Utility Geothermal Subcommittee*
  A utility geothermal subcommittee should be formed under the leadership of the Governor's Energy Office through which all action items related to utility geothermal power, direct use, and geothermal heat pump technologies would be considered and implemented. UGWG is in an exceptional position to receive feedback from utilities and consumers, while CO-SWG is well placed to address the needs of its potential consumers.

  A subcommittee comprised of utility, industry, state government, and other geothermal stakeholders will provide for effective communication between all interest groups. It will be devoted to coordinating efforts on addressing geothermal-related issues and ensuring maximum benefits for the partnership. The subcommittee could meet on a quarterly basis to identify activities, track progress and interface between the CO-SWG and UGWG.

- *Explore Mechanisms to Reduce Drilling Costs*
  Exploring strategies and mechanisms to reduce the cost of exploratory drilling for utility-based geothermal projects must be a priority action item. Other actions include:
  - Monitor the Department Of Energy's (DOE) Geothermal Technology Program budgets and determine if a GRED IV solicitation from DOE is forthcoming. The

  - Determine if there are opportunities to create a state-based incentive program to assist in cost-sharing development of drilling plans and exploratory drilling activities by utilities and/or project developers on behalf of utilities.

- *Participate in PUC Meetings*
  Utility geothermal subcommittee members should participate in hearings and working groups related to RPS revisions and refinements, and work toward the following goals:
  - Include a base load resource set-aside that boosts geothermal power project development by utilities falling under the RPS requirements.
  - Include a thermal energy or “kilowatt-hour equivalent” allowance in the RPS that encourages geothermal direct use project development by utilities.

- *Increase Geologic Investigations*
  The utility geothermal subcommittee should coordinate with the geothermal resource subcommittee to support increased geologic investigations in the state. Such explorations would help to locate areas of geothermal power production potential based on availability of 1) co-located geothermal resource temperatures and cooling water temperatures with adequate “delta T” to support power production, and 2) access to transmission and distribution lines.

5.0 POLICY RECOMMENDATIONS

While numerous policy recommendations were considered for inclusion within this report, it was ultimately decided to focus on four key recommendations.

1. Grants and loans
2. Resource assessments
3. Drilling incentives
4. State renewable purchases

These topics were deemed to have the most measurable potential for creating a political and economic climate conducive to expanded geothermal development.

5.1 GRANTS AND LOANS

- *Create a Low- Interest Loan Program*

In a 2004 paper entitled "Geothermal Policy Options for States," the National Geothermal Collaborative (www.geocollaborative.org) wrote:

"Twenty states have grant programs to support renewable energy in the commercial, industrial and government sectors and for schools and utilities. Some programs focus on research and development, but most aim to encourage the purchase and installation of renewable energy equipment. Programs vary in the amount offered—from a few hundred dollars up to $1 million— and some states set no limit. States also offer low- or no-interest loans to help citizens buy renewable energy equipment."

Colorado should follow the lead of these states by creating a low-interest loan program through the Colorado Governor's Energy Office. Providing and guaranteeing loans to both residential customers and commercial businesses would facilitate the state's geothermal development.

5.2 RESOURCE ASSESSMENTS

- *Explore Ways the State Could Support Assessment Activities*
  "Resource assessment is an important activity, as the current success rate for discovering new geothermal (hydrothermal) fields is about 20 percent. Most new fields are "blind" in that there are no surface manifestations of the existence of hot water at depth. Much of

the risk is up front, requiring investment in exploration, exploratory drilling, and resource assessment." [1]

Efforts to share information between state and federal agencies that have successfully developed geothermal direct-use projects – including businesses, companies, consultants, and contractors – should continue and expand. Entities should be encouraged to report on geothermal direct-use projects in industry trade magazines, such as greenhouse and aquaculture industry publications that provide visibility about geothermal technology to a broader audience.

5.3 DRILLING INCENTIVES

- *Develop Initial Stage Development Incentives*

While existing federal incentives (PTCs, accelerated depreciation and depletion allowances) are usually sufficient to spur development in the post-feasibility study stage, they are no help during the pre-feasibility study phase. To remedy this situation, state drilling incentives should be created to advance geothermal activity and enhancing capital availability.

5.4 STATE RENEWABLE PURCHASES

- *Increase Renewable Energy Purchase Requirements*

As contrasted from state Renewable Portfolio Standards (RPS), state renewable energy purchase requirements can differ greatly, but most states with such requirements apply them to state-owned facilities. Several states with state renewable energy purchase requirements do not have RPS laws.

Lead by example measures include:

- Establishing clean and/or renewable energy purchasing or generation goals for their own facilities.
- Requirements to obtain a certain percentage of electricity usage from clean renewable generation sources.
- A minimum clean energy purchase volume (in megawatt-hours) by a given date.

Lead by example measures may also take the form of goals for self-generation of clean or efficient energy, such as clean distributed generation or combined heat and power. These goals can be met through a variety of methods including onsite generation, purchasing clean renewable energy power products, or by purchasing renewable energy certificates. States that have requirements for implementing specific renewable energy measures without an aggregate goal are differentiated on the map seen in Figure 1. Colorado should continue to lead by example, by setting strict renewable usage standards for state buildings and facilities.

[1] - Roy Mink, DOE Program Manager of Geothermal Technologies, April 6 2006, testimony before the U.S. House Committee on Resources, Subcommittee on Energy and Mineral Resources.

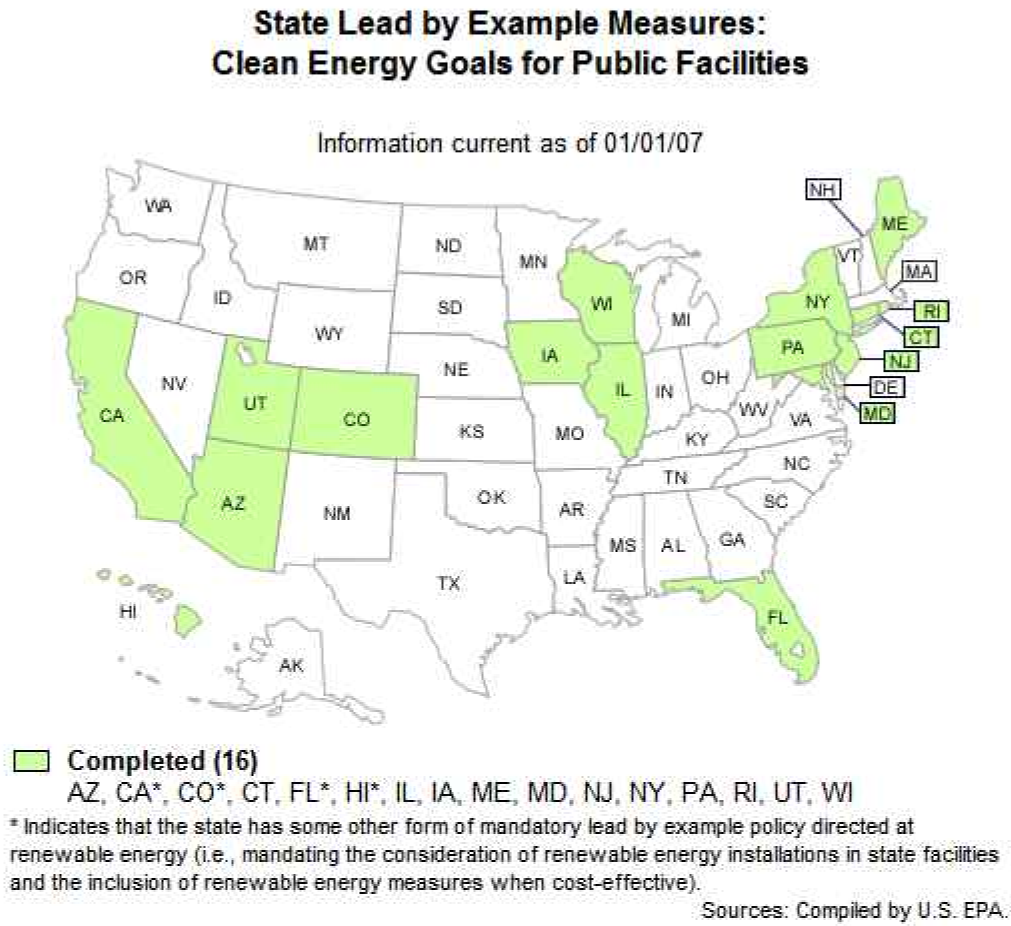

Figure 1. Map and text from “Clean Energy Goals for Public Facilities” pop-up box at http://www.epa.gov/cleanenergy/stateandlocal/activities.htm

6.0 FINANCIAL RECOMMENDATIONS

BACKGROUND

Currently there are a number of financing options available for small-to-medium generation and direct-use project development, including obtaining private financing, Small Business Administration loans, and federal programs including programs from the U.S. Department of Agriculture and the Department Of Energy.

BARRIERS

- Geothermal Projects are high risk with more than 30 percent of a project's costs coming from the initial exploration, confirmation, and feasibility study stage.
- PTC credits usually expire before a plant can capitalize on them.
- Existing federal incentives, including PTCs, accelerated depreciation, and depletion allowances aren't generally available in pre-study stage.

OPPORTUNITIES

- The current political climate may be favorable for creating new funding guarantees for exploration activities.

ACTION ITEMS

- The CO-SWG will host an investors' forum on October 19, 2007 in Montrose, CO. The forum will bring together investment professionals, resource developers, and landowners to discuss financial strategies to encourage development.

- Explore grant and credit programs to help bolster projects up to the completion of the feasibility study stage.

- Colorado should match private equity funds for drilling exploration if the drill site has received a positive recommendation from an independent geologist consultant based on surface measurement techniques.

7.0 MARKETING AND EDUCATION OUTREACH

BARRIERS

While the potential and use of geothermal energy has been around for decades, the public, as well as key stakeholders, have been slow to recognize the important role it can play in helping to ease the nation's energy shortfalls. In Colorado, where currently no geothermal electric generation is taking place, this is especially true. While most state residents and lawmakers are familiar with direct-use applications, they are less – or not at all – familiar with geothermal heat pumps or geothermal electric generation.

This lack of understanding is among the largest hurdles faced by the industry in the state. There are several recommendations to combat this. Key among them is a sustained effort by interested parties in educating the public, potential users, regulators, legislators, government policy makers, and financial institutions and advisors to the numerous advantages of geothermal.

Coupled with a lack of funding for the GeoPowering the West Program in 2007, many possible outreach activities will have to wait until possible funding resumes in 2008.

OPPORTUNITIES

With the continuing public dialog about how to best plan for our energy future, geothermal energy has a dynamic and unique story. By working closely with other industry groups and pursuing educational outreach opportunities, geothermal can take its place along side solar and wind as a prominent renewable energy resource.

To take full advantage of the political climate that is in favor of renewable energy, a full-time position should be created using private industry funding. This position should be housed outside the Governor's Energy Office to best allow them to coordinate with industry representatives and other key stakeholders, including state legislators and the state's national legislative delegation.

ACTION ITEMS

7.1 Conduct Educational Forums

- *Increased awareness is needed to boost geothermal energy projects in the state.* Implementing an educational forum or conducting workshops for state utilities (or co-sponsoring an event with neighboring states for all regional utilities) provides an excellent opportunity to highlight the benefits of geothermal technologies and discuss their applicability for utilities. These efforts will integrate the role of geothermal power, direct use, and heat pump technologies in utility resource and program portfolios or focus on them individually. Additionally, utility exhibit booths should be developed to provide information on geothermal technologies at suitable events. Efforts should be undertaken by in coordination with the proposed Colorado Geothermal Information Coordinator.

- *Educating state and federal legislators on benefits of geothermal technologies.*
  Only through legislative education efforts will geothermal be viewed as a renewable resource when considering various policy decisions. For example, the group can build off the success of the Arizona state working group who worked in conjunction with the state legislature to incorporate the thermal energy from direct-use applications into the state's Renewable Energy Standard requirements. The UGWG, CO-SWG , and proposed Geothermal Information Coordinator can provide factual information needed by policy makers to make decisions based on unbiased data and to ensure that geothermal capabilities are not overlooked when considering renewable standards. Most of the public is aware of the benefits of solar and wind technologies, but are unfamiliar with the full potential that geothermal resources have to offer.

- *Participate in UGWG Workshops*
  UGWG has planned a series of geothermal heat pump workshops to educate utilities and consumers on the benefits and applications of geothermal heat pumps. The Colorado workshop is scheduled to be held in 2008 and provides an excellent opportunity for the state working group to participate and leverage the event to a wider audience.

- *Collaborate on Webinar*
  UGWG will also host a series of webinars that address a variety of topics on geothermal to educate utilities on the opportunities and benefits that can be realized. UGWG, CO-SWG, and proposed Geothermal Information Coordinator can collaborate to develop a webinar that provides training on the GHP handbook and energy savings calculation tool developed by UGWG.

- *Partner with CRES*
  Establish geothermal track at Colorado Renewable Energy Society annual meeting to become the focal point of annual CO-SWG meetings.

- *Develop Speakers Bureau*
  Develop a Speakers Bureau of CO-SWG members coordinated by the proposed Colorado Geothermal Information Coordinator.

- *Work Closely with State Lawmakers*
  Outreach efforts should be undertaken by the proposed Colorado Geothermal Information Coordinator to determine the most effective and sustainable incentives to encourage development. This information should be provided to lawmakers for consideration. The Coordinator should also assist in or promote the drafting of legislation beneficial to all types of geothermal development. They should also identify and explore innovative financial mechanisms to encourage development, such as enterprise zones and municipal financing or bonds.

- *Explore Collaboration with Rural Cooperatives*

Work with rural electric cooperatives with a known geothermal resource base to explore potential projects within their service territories.

8.0 CONCLUSION

As recent and ongoing studies show, Colorado posseses more geothermal resources than previously thought. Many rural areas of the state could benefit significantly from developing their resources, creating new jobs in the power production, agricultural and aquaculture sectors.

Geothermal power production offers several advantages over other renewable energy production sources. Modern closed loop binary systems have virtually no emissions, a small plant footprint, low noise emissions, high reliability, and are base loaded. While Colorado has numerous direct use and aquaculture projects, the state currently has no electrical generation.

By ensuring that new and consistent funding continues to support resourcemapping projects, the state will have taken the most important step in attracting financial and resource development firms looking for projects with minimal risk.

Once mapping activities have been completed, a privately funded position should be created within a state university to lead industry outreach efforts. By identifying and actively supporting favorable policies and financial incentives for exploration and drilling activates, the state's geothermal industry can be jumpstarted, increasing the number of direct-use, power production, and heat pump projects.

9.0 APPENDICES

Appendix A **GeoPowering the West Colorado State Working Group Meeting Agenda – January 2007**

Appendix B **GeoPowering the West Colorado State Working Group Meeting Minutes – January 2007**

APPENDIX A

GeoPowering the West
Colorado State Working Group Meeting Agenda
Western Area Power Administration, Lakewood, Colorado
January 31, 2007
8:30 A.M. – 4:00 P.M.

8:30-9:00
Welcome & Introduction of Working Group Attendees
Colorado Governor's Energy Office (GEO)

<u>Setting the Scene: Key Geothermal Issues</u>
9:00-9:15
Geo-Powering the West Initiative: Goals of the Program
Curtis Framel -- Department of Energy (DOE)

Q&A

9:15-9:45
Colorado Geology: Geothermal Energy in Colorado - A New Look
Matt Sares – Colorado Geological Survey

Q&A

9:45-10:25
Geothermal Powered Generation: An Overview of Technologies
Dan Schochet – Ormat Technologies
TBD – United Technologies Corporation (invited)

Q&A

10:25-10:40
Break

10:40 – 11:00
Geothermal (Earth Coupled) Heat Pumps: Large Commercial Applications
H. E. Johnson – EnLink Geoenergy Services

11:00-11:30
Investors Viewpoint: Financing Geothermal Development

Robert Banack – Dundee Securities Corporation

Q&A

11:30-12:00
Policy Challenges & Opportunities: Reducing Barriers to Geothermal Development
Paul Thomsen – Ormat Technologies

Q&A

12:00-1:00
Box Lunch with Presentation & Discussion: A Vision of Colorado's Geothermal Future
Joe Bourg – Millennium Energy LLC / Sandy Glatt – DOE

<u>Working Group / Steering Committee Discussions (All Participants Welcome)</u>
1:00-4:00
Working Group Objectives
GEO

- Overview of Working Group & Steering Committee deliverables: Strategic Plan, website and Investors' Forum.
    - Discussion/approval of Strategic Plan purpose and outline.

2:00 – 2:15
Break

2:15- 4:00

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    - Discussion of website objectives and content.
    - Discussion of the Investors' Forum – objectives, alternatives.
- Development of subgroups to work on all of the above (categories and responsibilities).
- Procedural questions & next meeting time schedule

4:00
Adjourn