
Arnold Schwarzenegger
*Governor*

# A DEVELOPMENT PLAN FOR GEOTHERMAL ENERGY IN CALIFORNIA: CHALLENGES TO AND SOLUTIONS FOR MEETING CALIFORNIA'S GEOTHERMAL ENERGY FUTURE

**PIER FINAL PROJECT REPORT**

*Prepared For:*
**California Energy Commission**
Public Interest Energy Research Program

*Prepared By:*
**California Geothermal Energy Collaborative**

October 28, 2008
CEC ***-2008-***

***Prepared By:***

California Geothermal Energy Collaborative
Davis, California
Contract No. 500-99-13

Paul Brophy, EGS, Inc
Carol Bruton, Simbol Mining
Judy Fischette, California Geothermal Energy Collaborative
Karl Gawell, Geothermal Energy Association
William Glassley, California Geothermal Energy Collaborative
Laurie McClenahan Hietter, MHA
Mack Kennedy, Lawrence Berkeley National Laboratory
Charlene Wardlow, Ormat Nevada, Inc.
Jonathan Weisgall, MidAmerican Energy Holdings, Inc.
***Primary Authors***

Pablo Gutierrez
***Project Manager***

Martha Krebs, Ph.D.
***Deputy Director***
***Energy Research and Development Division***

Claudia Chandler
***Assistant Executive Director***

Melissa Jones
***Executive Director***

## DISCLAIMER

**This report was prepared under contract to the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees, or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the Energy Commission nor has the Commission passed upon the accuracy or adequacy of the information in this report.**

# ACKNOWLEDGEMENTS

Reviews and comments by Elizabeth C. Battocletti, and John W. Pritchett materially improved the document and are gratefully acknowledged.

Please use the following citation for this report:

Brophy, Paul (EGS, Inc), Carol Bruton (Simbol Mining), Judy Fischette (California Geothermal Energy Collaborative), Karl Gawell (Geothermal Energy Association), William Glassley (California Geothermal Energy Collaborative), Laurie McClenahan Hietter (MHA), Mack Kennedy (Lawrence Berkeley National Laboratory), Charlene Wardlow (Ormat Nevada, Inc.) and Jonathan Weisgall (MidAmerican Energy Holdings, Inc).. ***A Development Plan for Geothermal Energy in California: Challenges to and Solutions for Meeting California's Geothermal Energy Future***. California Energy Commission. CEC-***-2008-***.

# PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research, development and demonstration that will help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards millions of dollars to conduct the most promising public interest energy research. This effort is accomplished by partnering with Research, Development and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on six RD&D program areas:

- Residential and non-residential buildings end-use efficiency
- Industrial, agricultural and water end-use energy efficiency
- Renewable energy technologies
- Environmentally preferred advance generation
- Energy-related environmental research
- Strategic energy research

What follows is a task report by the California Geothermal Energy Collaborative. The report is entitled "A Development Plan for Geothermal Energy in California". The purpose of this report is to lay a foundation for strategic planning efforts that will consider how best to accelerate the contribution of geothermal energy usage to meet PIER efforts that support state-mandated renewable energy goals and greenhouse gas emission reductions. The Energy Commission has funded this work pursuant to the PIER Program Contract Number 500-99-13 between UCOP CIEE and the Energy Commission. This project contributes to the Renewable Energy Program area.

# TABLE OF CONTENTS



# LIST OF FIGURES

# ABSTRACT

California has established aggressive goals to increase the use of renewable energy resources (via its Renewable Portfolio Standard [RPS] goals) and decrease greenhouse gas (GHG) emissions (Assembly Bill (AB) 32 – mandated GHG goals). Geothermal energy has historically been the most significant renewable energy source in the state. However, the growth of geothermal energy has stalled, despite overwhelming evidence that a large, untapped resource base exists. The California Geothermal Energy Collaborative (CGEC) has undertaken an effort to identify the key challenges that must be overcome to address this problem, and proposals for resolving them. This report summarizes the results of that effort. It is intended that these results will provide the framework for development of a detailed R&D roadmap that can contribute to the Strategic Renewables Roadmap currently being developed by the Renewables Energy Generation Research Office within the California Energy Commission.

Three key areas were identified that, if addressed, could significantly improve the ability of geothermal energy to contribute to the state's ability to meet its RPS and AB32 goals – resource assessments, permit and lease issues, and policies.

Current resource assessments of the incremental geothermal resource base vary by nearly an order of magnitude, from about 3,000 MW to over 24,000 MW and higher. This range in resource estimates reflects contrasting assumptions and assessment methodologies, as well as uncertainties in the available databases. There is good scientific reason to believe that hidden resources exist throughout the state that could significantly increase those resource estimates, but technology is currently inadequate to pinpoint those resources or evaluate their quality. Also, resources that could support distributed generation, areas with enhanced geothermal potential (i.e., so-called "Enhanced" or engineered geothermal systems, also known as EGS), and other advanced technology-based exploitable resources have not been identified in state efforts, and are only beginning to be evaluated at the federal level. In addition, existing assessments have not considered the impact installation of high-efficiency GSHP systems would have by displacing electric use for HVAC.

Streamlining permit and lease processing is impeded by inconsistent local regulations, misunderstanding of geothermal systems and their benefits and impacts, and inadequate public awareness of resource availability. There is also insufficient educational material and training available for the development of local industries. The absence of standards within the regulatory and industrial sectors compounds confusion over how best to promote the use of geothermal resources.

Moving renewable energy technologies to market depends upon supportive policies and incentives. Loss of Federal support has complicated the ability to develop policies that support technology growth. This situation exacerbates an already challenging financial environment for investment in geothermal power production since this technology is often heavily weighted toward initial investment and long time-to-market. To address these issues, an analysis of productive incentive strategies needs to be provided to regulators and legislators, in order to encourage investment. Policy recommendations and examples, and supporting analysis of impacts, need to be developed to assist the legislative and regulatory communities in their analysis of useful approaches for encouraging resource growth. They should be developed for the full range of technology/resource possibilities, ranging from distributed power and heat to large scale EGS projects.

Specific recommendations for each area were developed and are detailed in the body of this report.

**Keywords**: Geothermal energy, resource assessments, permitting, leasing, policy development, priorities, strategic planning, research

# BACKGROUND

California's Renewables Portfolio Standard (RPS) was established in 2002 by Senate Bill 1078. That Bill required the state's retail sellers of electricity including investor-owned utilities (IOUs), electric service providers (ESPs), and community choice aggregators (CCAs) to procure 20 percent of their retail electricity sales with eligible sources of renewable energy by 2017. That procurement would amount to an estimated 9,000 MW of power generation from renewable sources. California's energy agencies subsequently committed to achieving the 20 percent target by 2010. This 20 percent target was recently codified by the enactment of Senate Bill 107 (Simitian and Perata, Chapter 464, Statutes of 2006), which took effect on January 1, 2007.

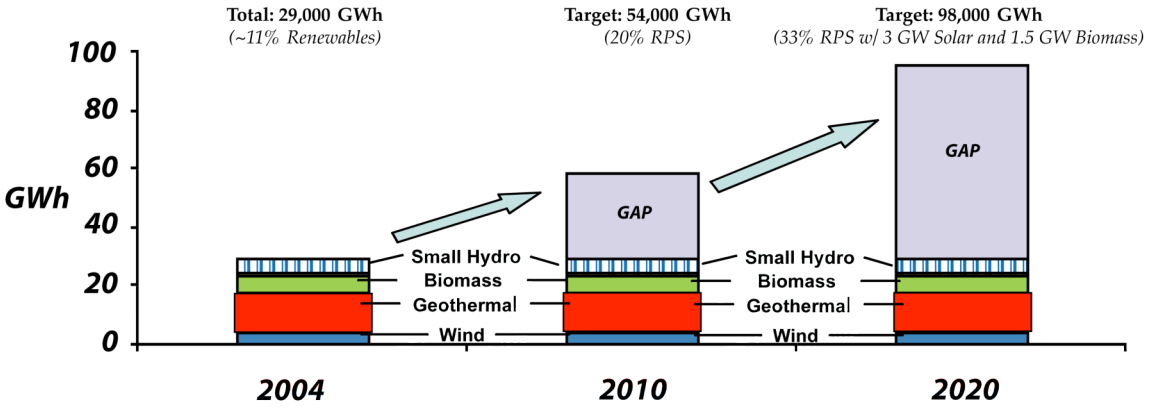
On September 27, 2006, Governor Schwarzenegger signed Assembly Bill 32 (AB 32). The purpose of that order was to put California on the path toward reducing greenhouse gas emissions by establishing target emission levels:

- By 2010, reduce greenhouse gas emissions to 2000 levels
- By 2020, reduce greenhouse gas emissions to 1990 levels
- By 2050, reduce greenhouse gas emissions to 80 percent below 1990 levels.

The RPS and AB32 goals can only be achieved through accelerated growth of renewable energy sources. Geothermal energy is currently the largest single renewable energy source in the state, contributing approximately 5% of the state's electric power needs. It has the potential to provide the largest incremental capacity for power generation and greenhouse gas reductions, if key challenges can be addressed. This document provides an analysis of those challenges, and approaches for addressing them.

## Geothermal Energy in the State of California

Geothermal energy has historically been the most significant renewable energy source in the state. In 2005, 5.0%, or 14,379 gigawatt hours (GWh), of California's electric energy generation came from geothermal power plants, accounting for nearly half of all renewable energy (Figure 1). At that time, California's geothermal capacity (2,492.1 megawatt (MW) installed) exceeded that of every country in the world.




Data Sources: 2004, CEC Electricity Report which includes all renewables in the State, not just IOUs; 2010 and 2020, PIER Renewables Projections.

Figure 1. Power production in 2004, by renewable energy source. Also shown are the projected RPS targets and the respective renewable power production needs (labeled "GAP") for 2010 and 2020.

The total new geothermal power production potential for the state is a matter of uncertainty. There currently is under development 921 to 969 MWe of capacity, which is anticipated to come online within the next five years. Estimates of the undeveloped total new power production potential vary widely. The Geothermal Energy Association (GEA), in a report to the California Geothermal Energy Collaborative (2006), summarized reports assessing the potential geothermal resource in conventional hydrothermal systems. The GEA report documents that resource assessments vary between 3,186 and 24,750 MWe. At a capacity factor of 0.9, this resource power production potential is between ~23,000 and 189,000 GWh. More recently, the United States Geological Survey (USGS) concluded that the electric power generation potential from identified and undiscovered hydrothermal resources in California had a mean probability of being 16,744 MWe, which falls within the range reported in the GEA (2006) report. The USGS went on to consider the resource potential of so-called enhanced geothermal systems (EGS) as well. EGS systems are similar to conventional hydrothermal systems, except they require engineering enhancement to increase the rate and volume of fluid movement through hot subsurface rocks. They often also require deeper drilling to tap the resource. The USGS estimate of the electric power generation potential for EGS in California had a mean probability of being an addttional 48,100 MWe.

Despite significant differences among the various estimates in the size of resource base, it is abundantly clear that geothermal power has the potential to meet most, if not all, of the power production "GAP" the state currently faces in trying to meet its RPS goals. It is also clear, however, that more work needs to be done to refine the resource estimates and reduce uncertainty.

California also has a history of utilizing lower temperature geothermal resources in a variety of applications. There are over 120 sites throughout the State where geothermal fluids are being used for aquaculture, greenhouse heating, spa and resort facilities, and district heating. There are an additional approximately 400 ground source heat pump (GSHP) installations for residential, school and commercial building heating and cooling. These facilities have the potential to decrease electric loads, thus reducing the RPS targets and improving the ability to meet AB32 standards.

However, meeting the RPS and AB32 goals will require accelerating geothermal resource use. For the most recent six-year period, 2000 to 2005, the average annual growth rate was 1.3 % with a total growth of only 6.9 %. This growth rate is inadequate to fully exploit even the most conservative estimates of California's resource base. By comparison, for the six-year period 1983 to 1988, the total growth was over 100 %. The average annual growth rate for power production over that period was approximately 8.7 %.. Similar growth rates are need over the next few years in order for geothermal power production to achieve its potential and contribute to meeting RPS and AB32 goals.

Growth in the utilization of low temperature resources also needs encouragement. Very few new direct use applications have been brought to completion within the last five years. And, despite a national surge in GSHP installations, with somewhere between 600,000 and 1,000,000 installed units as of 2006, growth in California has been stagnant.

The California Geothermal Energy Collaborative (CGEC) board and staff considered means whereby geothermal development could be encouraged. A task force was formed with member experts from industry, academia, private business and trade groups to develop a plan for accelerating thoughtful exploitation of this resource. A draft analysis and plan was presented at a public workshop on June 20, 2007 at Heidrick Agricultural History Museum in Woodland, California. The purpose of the workshop was to solicit comment on the draft plan, and to discuss issues and options. Forty-five stakeholders attended. The Geothermal Collaborative staff also participated in a Direct Use Network panel focused on direct use and ground source heat pump applications. The document was revised on the basis of comments received at those venues, and was made available for further public input at the California Geothermal Energy Collaborative Summit meeting, held in Sacramento on July 30, 2008. The current document reflects all comments received as of October 20, 2008.

The remainder of this document summarizes the findings. The intent is to provide a framework for discussion that will lead to a consensus geothermal development plan that will contain specific recommendations for encouraging development of California's geothermal resources. It is anticipated that the development plan will inform and guide policy makers, lawmakers, regulators, investors, researchers, educators and developers, and improve recognition of geothermal energy among the public at large. It is expected that this effort will inform the ongoing PIER Road-mapping exercise, providing the state with guidance regarding the best means for improving the rate at which renewable energy resources, and geothermal in particular, can contribute to the state's needs.

# DISCUSSION

Three focus areas were identified as crucial for improving development of geothermal resources:

- Resource assessment (Mack Kennedy and Paul Brophy)
- Permitting and leasing process (Charlene Wardlow and Laurie McClenahan Hietter)
- Regulatory and marketplace incentives (Karl Gawell and Jonathan Wesigall)

These are discussed separately below. The focus area leaders who took responsibility for assembling the material for each area are indicated above.

## Resource Assessment Focus Area

Despite a long history of resource use, the geothermal resource base in California remains broadly uncertain. The existing sources of information (CGEC Geothermal Summits, CEC reports and documents, USGS Circular 790 and other independent studies) have focused exclusively on the Known Geothermal Resource Areas (KGRAs), and utilized differing assumptions and methodologies to obtain estimates of the size of the resource base. The state of this knowledge was summarized in the GEA 2006 report referenced above. There currently does not exist within the geothermal community a consensus estimate of the high temperature resource base contained within the KGRAs, nor the fraction of that resource that is economically extractable.

Past resource estimates have tended to exclusively focus on known resource areas amenable to development using existing, "standard practice" technology. However, recent advances in binary systems, storage technology, and distributed generation strategies suggest that lower temperature resources can, in favorable circumstances, be suitable for power generation. These newer approaches to resource use would increase the overall resource base, if included in assessments. This needs to be done.

Since most of these reports were published, *The Future of Geothermal Energy* report ("the MIT report") was published. This document emphasized the feasibility of developing "Enhanced" or engineered geothermal systems (EGS), which usually are deeper than most hydrothermal systems, and require reservoir stimulation for development and exploitation. Although still a nascent technology, it is rapidly gaining attention as a potentially vast resource. A detailed evaluation of EGS potential within California is needed.

Assessments have almost exclusively focused on resource sites where surface manifestations suggest that a resource exists at depth. However, it is likely, from geological arguments, that the state possesses geothermal resources that are hidden below surface deposits that have no indication of the presence of a subsurface geothermal resource. Encouraging the development of new techniques for finding these "hidden" resources should be pursued.

Compounding the resource assessment issue is the fact that a well-documented evaluation of the magnitude of the moderate and low temperature geothermal resource base that could be utilized for direct use or ground source heat pump (GSHP) applications does not currently exist. Although such applications do not generate power, they do reduce load on the electrical grid by directly substituting thermal energy for electricity and contribute to the reduction of greenhouse gases.

Principle impediments in resolving these issues have been:

- The wide variety of resource types in California;
- The restricted number of capable exploration entities;
- The need for development of exploration tools to identify hidden resources;
- The lack of understanding of resource risk, and
- Restricted access to lands.

To encourage accelerated development of geothermal resources, a clearer definition of the geothermal resource base is required. To accomplish this, the following recommendations are made:

- Develop a clearer understanding of all resource types and their geologic and structural settings
- Develop and promote incentives for exploration companies
- Improve funding for research and development for exploration tools
- Improve education regarding real and perceived risk so that more thorough exploration and evaluation of a potential resource can be undertaken
- Develop maps that identify lands that have a long term potential for producing fluids from all types of geothermal resources
- Develop a strategy for utilizing and demonstrating distributed generation systems
- Implement a new R&D program for the development of generation systems using low and moderate temperature resources
- Develop cost sharing strategies with federal partners

## Lease and Permit Focus Area

Development of geothermal resources must be done using methods and technologies that minimize impacts on air, water and cultural resources, regardless of the type of application to be developed. A large body of regulations exists to ensure protection of these resources. Guidance about how best to satisfy these regulations is provided by the recent publication of the "Geothermal Permitting Guide" produced by Blaydes & Associates for the California Geothermal Energy Collaborative, and is available at the Commission website (http://www.energy.ca.gov/pier/final_project_reports/index.html).

Although intended to assist developers in meeting regulatory requirements as efficiently as possible, the Guide also documents the multiplicity of regulations, regulatory agencies and rules that must be satisfied in order to obtain the necessary permits for project approval and development.

Compounding the challenge to meet these requirements are additional hurdles a potential geothermal project faces. These include:

- A lack of knowledge of geothermal energy, inadequate understanding of its benefits or examples of successful applications, and inaccurate or insufficient information concerning its impacts on the part of regulators and the public;
- A lack of coordination between responsible agencies for licensing and permitting;
- Lack of a standardized approach for permit applications.

The consequence has been that the permitting process can require years to obtain final approval for a project.

To streamline the permitting and leasing process, the following recommendations are made:

- Develop an education and training program that will elucidate the environmental and social realities of geothermal energy usage, including examples, both nationally and internationally, of its successes. Such a program would be modularized to address different audiences (regulators, legislators, and the general public), with the goal of establishing a common basis of knowledge so that informed decisions can be quickly made regarding proposed geothermal projects. The program should be portable and used throughout the state and with all media outlets.
- Establish a "best practices" approach that could be utilized throughout the State to streamline consideration and review of lease applications by governing agencies. This would include identifying activities that can be designated as Categorial Exclusions or Exemptions under California Environmental Quality Act and National Environmental Policy Act (NEPA) rules; defining all typical exploration and development activities in the BLM Programmatic Environmental Impact Statement to streamline future NEPA analysis; get the full range of geothermal activities defined in the Programmatic EIS so that individual projects can pull out relevant sections to their projects, as needed.
- Create a geothermal "agency SWAT team" to provide educated and dedicated agency personnel to deal with interagency coordination. Give them responsibility to develop and administer memoranda of understanding between agencies.
- Encourage improved staffing of state and local positions with trained professionals for review of lease and permit applications.
- Hold open houses at geothermal facilities
- Improve communication with Indian Tribes and involve them in the decision making process.
- Prepare a follow-up document to the "Outreach Principles and Comment Analysis Report" to provide case studies of producing projects to support mitigation success
- Coordinate training for tribes, industry, and agencies on the Section 106 process under the National Historic Preservation Act

## Governmental Policies & Marketplace Focus Area

Improving the contribution of geothermal energy to the nation's energy needs depends upon supportive policies and incentives, and a favorable market. In the past, the Department of Energy has been the largest single source of funds for geothermal research, development and demonstration projects. Until recently, this commitment of federal funds to support that work has been consistent, reflecting recognition that geothermal energy has a significant role to play in the country's energy future.

However, over the last year federal policy and budget decisions have reduced or eliminated funding for geothermal programs in the Department of Energy. The result has been disruption of a broad range of projects. Although there currently are discussions about restoring funding to geothermal programs in the Department of Energy, there remains uncertainty about the magnitude of that support and how it will be allocated.

In addition, while there are numerous examples of economically robust geothermal facilities, bringing new projects on-line is costly and time-consuming. The leasing and permitting hurdles outlined above, as well as numerous other challenges to exploration and development, impede the realization of return on investments. As a result, financing for geothermal projects can be difficult to obtain.

The key challenges that must be addressed are:

- An inadequately defined resource, which makes it difficult to obtain financing for development
- Development rights need to be better established, streamlined and supportive of those organizations capable of bringing projects to a timely completion
- Incentives and price supports do not sufficiently address the unique needs of geothermal projects, including the permitting and leasing environment, that impact development time
- Recognition that geothermal energy is more than power production. Direct use applications and ground-source heat pumps can provide significant energy savings for the state. But, such systems need supports and incentives that are vastly different from those for the power industry.

Many of the actions that would improve the policy and market environment are the same as those outlined in the other Focus Areas. Additional actions that should be taken include:

- Reduce the uncertainty of resource estimates by developing a detailed assessment that will build on the current effort of the USGS.
- Establish consistent, long term policies that encourage financing for and investment in geothermal resources. Examples include:
  - Establish Feed-in Tariffs Tariffs for geothermal resources, which would remove the uncertainty of project financing by providing a fixed price of power for a specified period of time
  - Continue to make Federal Clean Energy Bonds (CREBS) available to municipal utilities and cooperatives
  - Extend the Federal Production Tax Credits (PTC) for geothermal power
  - Develop a pre-production equivalent of PTCs for geothermal facilities in the development stage, to encourage investment
  - Provide incentives for drilling rigs dedicated to geothermal development

- Develop policies that distinguish between power production facilities and other applications, taking into account the unique attributes and needs of each application. Examples include:
    - Promote the application of ground source heat pumps and direct use applications in "Green" buildings.
    - Include all geothermal technologies in the BLM's Programmatic Geothermal Environmental Impact Statement
    - Establish a standard negative declaration under CEQA for certain types and aspects of direct use and ground source heat pump applications.

# PRIORITIES

The above summary of needs and potential means for addressing them is extensive. Not all can be accomplished at once, and some, of necessity, require sequencing. Discussion and debate among stakeholders has led to the following list of high priority efforts. This tabulation should be viewed as a preliminary step in establishing a Geothermal Road Map that will identify specific needs and an appropriate timeline and funding priorities for the next 5 years. These priorities are presented in no ranked order.

Priority: Develop educational and outreach efforts so that policy makers and the public better understand the benefits of geothermal energy, and regulators can intelligently streamline the permitting process.

- Using the National Geothermal Collaborative's *Outreach Principles and Comment Analysis Report"* as a starting point, gather the most up-to-date information on geothermal systems, develop educational modules tailored to specific audiences, and aggressively use them in traveling educational programs and courses.
- As part of the educational program, develop a new perception about geothermal energy that is similar to that currently enjoyed by other renewable technologies.
- Develop a well-designed internet portal for the general public, interested professionals, designers and architects so that information and data are easily obtained and used.
- Undertake efforts to coordinate state, federal and local agencies so that a uniform "best practices" approach can be applied in the permitting and leasing process. Include templates for various applications that can be used state-wide.

Priority: Establish a taskforce to develop prototype policies that will encourage investment in geothermal energy, and educate the policy community about these.

- Describe incentives (rebates, credits, etc) that past history has shown would be useful for encouraging investment in geothermal power production, installation of ground source heat pumps in buildings and homes, and development of direct use applications.
- Develop prototype policies that encourage using ground source heat pump systems in public buildings

- Develop prototype policies that encourage the development of distributed systems in areas that possess geothermal resources but are not advantageously located with respect to transmission infrastructure
- Suggest incentives that would encourage exploration and development of exploration tools.

Priority: Develop a "next generation" assessment of the entire geothermal resource base.

- Build on the current US Geological Survey effort by extending it to higher resolution coverage of known high temperature resource areas, as well as expand it to include potential EGS, moderate, low temperature and hidden resource areas. Develop for this effort risk assessment methodologies similar to those employed by the USGS for its petroleum resource assessments. Seek a consensus within the community for this methodology, and identify data and research needs to improve it.
- Work with the California State Geologist's Office, and other entities, to assemble detailed scientific data sets for individual resources, including all archived data, so that the resource database can be readily updated as new technologies evolve. Make the database retrievable through web-based access. Include descriptions of the conceptual models that have been developed for each resource, identify the data needs required to test the models so that a consensus model for the areas can be developed. Use the models to identify lowest-risk drilling targets, if appropriate.
- Support efforts that employ the databases developed above to identify sites with a high potential for resource exploitation. Include in this effort the development of scenario-based analyses of the impact resource development would have on the State's effort to meet RPS and AB32 goals. Include consideration of likely "hidden" resource locations.
- Encourage development of technologies that will economically address the problem of finding resources that have no surface expression. Include consideration of hybrid remote sensing methods coupled with land-based geophysical measurements, isotopic analyses of soils and waters, and water district historical data records.

# REFERENCES


Blaydes, P., 2007. *California Geothermal Permitting Guide*. California Geothermal Energy Commission Report CEC-500-2007-027.

Gawell, K., 2006. California's Geothermal Resource Base: Its contribution, future potential, and a plan for enhancing its ability to meet the state's renewable energy and climate goals. Geothermal Energy Association Report to the California Geothermal Energy Collaborative. CEC Contract 500-99-013, subcontract C-05-29.

Lovekin, J.W., Sanyal, S.K., Sener, A.C., Tiangco, V., and Gutiérrez-Santana, P., 2006. Potential Improvements to Existing Geothermal Facilities in California. GeothermEx report to CEC-PIER.

Muffler, L.J.P., 1979, Assessment of Geothermal Resources of the United States--1978, U.S. Geological Survey Circular 790, 163 pp.

Petty, S., Livesay, B.J., Long, W.P. and Geyer, J., 1992. Supply of Geothermal Power from Hydrothermal Sources: A Study of the Cost of Power in 20 and 40 Years. Contractor Report, Sandia National Laboratory.

Tester, J.W., Anderson, B.J., Batchelor, A.S., Blackwell, D.D., DiPippo, R., Drake, E.M., Garnish, J., Livesay, B., Moore, M.C., Nichols, K., Petty, S., Toksoz, M.N. and Veatch, R.W. Jr., 2006. ***The Future of Geothermal Energy***. Massachusetts Institute of Technology, Boston, MA.

Williams, C.F., Reed, M.J, Mariner, R.H., DeAngelo, J. and Galanis, S.P., Jr., 2008. Assessment of moderate and high temperature geothermal resources of the United States. U.S. Geological Survey Fact Sheet 2008–3082, 4 p.