California's Geothermal Resource Base:

Its contribution, future potential, and a plan for enhancing
its ability to meet the states renewable energy and climate goals.

Karl Gawell, Executive Director
Geothermal Energy Association

Prepared for
Elaine Sison-Lebrilla, Commission Project Manager
PIER Program Area: Energy Research and Development Division
William Glassley, Geothermal Programs-Technical Manager

California Geothermal Energy Collaborative
California Institute for Energy and Environment,
University of California, Office of the President
Oakland, California

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Legal Notice

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Any opinions in this document are solely those of the author, and do not necessarily represent the views of the contributors, GEA, CEC, or the CGEC.

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Preface

Estimating the exploitable geothermal resources of the State is a difficult and ongoing effort. Although some resources are readily located through surface manifestations, such as geysers and hot springs, many remain hidden from view. Indeed, an important topic of current research in the Earth Sciences is how best to detect and estimate the size of these hidden resources. Once a resource is identified, an additional challenge is evaluating whether it can be reasonably exploited from an economic, environmental or regulatory perspective. Since these perspectives are responsive to changing social conditions, any resource assessment must be understood as a snapshot in time.

This report provides a summary of recent estimates using a variety of methodologies. It is a thoughtful review of available information, and objectively presents the range of reported resource values. As will be noted, that range is large, and reflects the differing estimation approaches used by the various groups doing the assessments. It is the intent of this report to call attention to the diversity of estimates, as a means of encouraging new work to refine measurement techniques and estimation methodologies. Suggestions at the end of the document for improving resource assessments are intended to stimulate discussion and consideration of ways in which California's geothermal resource base can become more precisely resolved. It is with that goal in mind that this publication is produced.

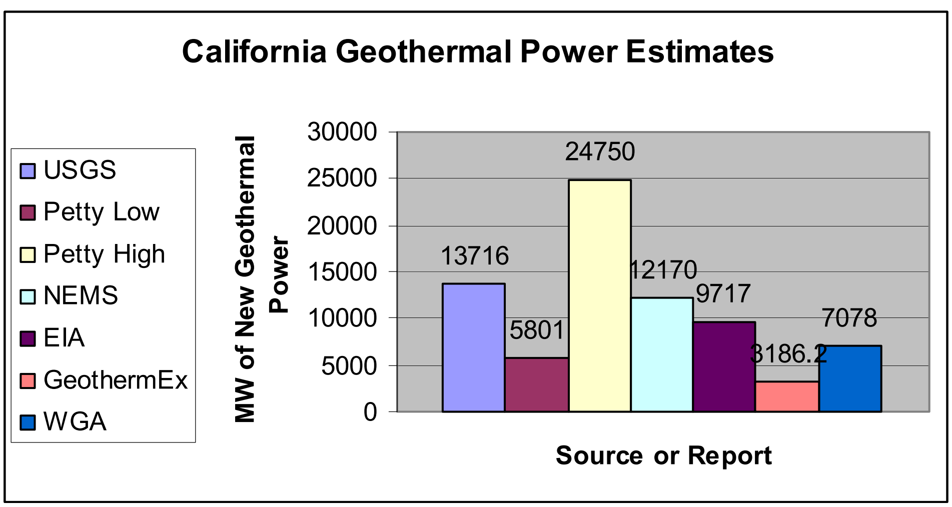
William E. Glassley
California Energy Commission
Research and Development Office

Summary

This white paper proposes that the California Geothermal Energy Collaborative (CGEC) begin working towards a California Geothermal Development Plan. The potential for geothermal resources to contribute to the state of California's energy goals is far greater than most imagine. Notwithstanding that potential, a business as usual approach toward resource identification and development will not result in these resources being developed in a timely manner. Institutional non-responsiveness within State and Federal governmental agencies, and risk issues with investors and developers combine to reduce what could be economically achieved to meet state energy goals. This proposal addresses those issues by proposing a series of steps for the CGEC to take.

Geothermal resource studies strongly indicate that California could support significant increases in renewable energy production to meet the state's Renewable Portfolio Standard and Climate Change goals. Moreover, an examination of those studies and current information about the potential for expanded production through new technology and applied engineering would indicate that the geothermal resource base could supply more power than is currently used by all of the states investor-owned utilities combined.

A Comparison of Recent Geothermal Power Supply Estimates for California

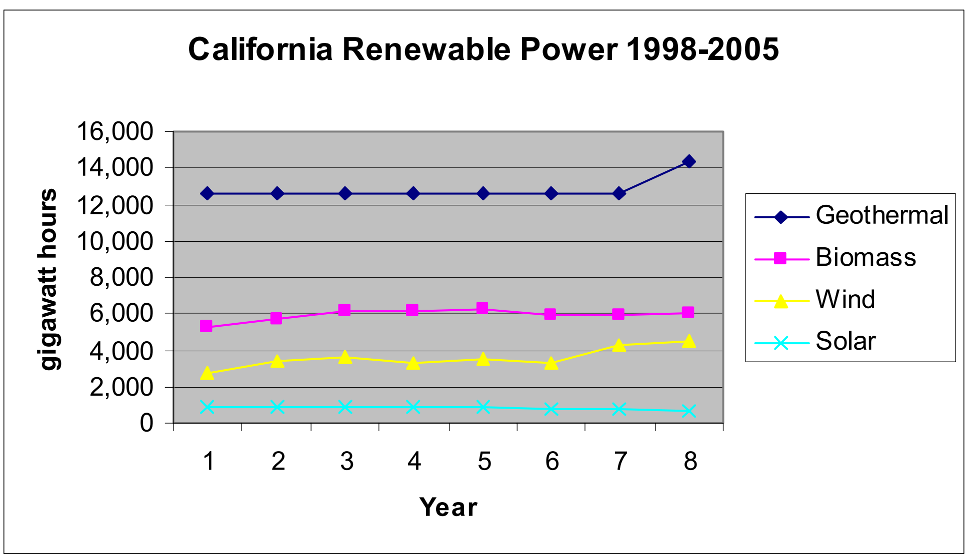


Geothermal Resources – A Major Renewable Energy Source

Geothermal energy continues to be the major renewable energy provider to California's electricity system. As California looks forward to expanded renewable energy production, geothermal resources are a critical part of the mix. They provide a uniquely reliable and continuously producing energy source, which helps balance the state's renewable portfolio.

Figure 1 presents the amount of electric power provided by the major renewables in California between 1998 and 2005. This figure shows that geothermal has maintained a strong and growing share of California's power supply. Geothermal energy makes a significant contribution to the state, and its past performance and future potential should both be recognized. Coupled with its large potential capacity, geothermal energy also offers key advantages compared to wind and solar energy: it is ideally suited to baseload (24/7) operation that intermittent resources cannot provide economically. And compared to biomass-derived energy, geothermal energy offers a major potential advantage in fuel-price stability and lower air emissions.

Figure 1: California Power Generation from Renewable Resources 1998-2005[1]



The Potential of California's Geothermal Resource Base

"A fundamental aspect of any energy policy is a credible assessment of the nation's energy natural resources," the American Association of Petroleum Geologists (AAPG) testified to Congress.[2] Geothermal developers agree—assessment is the first, crucial step towards new development. AAPG continued: "Based on events this winter, there is clearly a critical need to address energy policy if our nation hopes to preserve its economic might, and continue to create jobs and wealth across our great land. A reliable supply of affordable energy is vital to our continued prosperity. The ability to access estimates of oil and gas supplies, reserves, and resources is essential for development of a sound energy policy and strategy by the federal government."

"Given these significant increases in projected energy demand, and the electricity curtailments and natural gas price spikes of this past winter, the public must be assured that the nation can indeed supply the energy required to fuel our economy in the 21st Century. It is the job of the USGS and MMS to quantify the nation's energy mineral resources."[3]

The statement of APPGs experts are usually accepted when applied to oil, natural gas, and even coal, today's major energy sources. But, the need for resource assessment for renewable energy resources is not equally appreciated. Renewable resources are expected to be major contributors to the nation's energy supply, and understanding their national and state resource bases is equally important. While renewable resources are often thought of as being very large, how much energy they can provide is bounded by considerations of the available technology, cost, and resource availability. Failing to understand their limitations can lead to false expectations about their performance and be counterproductive in the longer run.

Defining the Resource Base – Choosing your terms

Geothermal and oil reserves are essentially the same types of commodities, and should be defined similarly. Like oil reserves, a geothermal reserve estimate is based upon a series of variables at a specific point in time. No single number for geothermal reserves is correct over time or under all assumptions because technology and knowledge change. Of course, the actual geothermal resources change only at a geologic pace. But our understanding of them must improve to keep pace with our energy demand, and to help foster technology advances needed to economically use this clean form of energy.

Oil is commonly viewed in terms of reserves and resources using the following definitions, which are similar to terms for geothermal resources.

- *Reserves* are the portion of *identified* resources that can be economically extracted and exploited using current technology.
- *Resources* include all fuels, both identified and unknown, and constitute the world's endowment of fossil fuels.[4]

Or, as Colin Williams of the USGS proposed at the 2005 California Geothermal Summit:[5]

- *Reserve*: The identified portion of the resource that can be recovered economically using existing technology
- *Resource*: The portion of the resource base that can be recovered as useful heat under current and potential economic and technological conditions

A slightly more detailed approach used for oil and gas classifies reserves in three categories. Under this approach, oil reserves are divided into three classes primarily along the lines of geological risk — of the probability of oil existing and being producible under current economic conditions using current technology. The three categories are proven, probable, and possible reserves.

- **Proven Reserves** - defined as oil and gas "reasonably certain" to be producible using current technology at current prices, with current commercial terms and government consent. Generally this includes those having a 90% certainty of being produced.
- **Probable Reserves** - defined as oil and gas "reasonably probable" of being produced using current or nearly available technology at current prices, with

current commercial terms and government rules and regulations. Generally, this refers to those having a 50% certainty of being produced.

- **Possible Reserves** – defined as those having a chance of being developed under favorable circumstances. Typically, this category includes those having a 10% certainty of being produced.[6] (Adapted from Wikipedia[7])

Each of these terms can be applied to geothermal. The California geothermal resource base has proven, probable, and possible reserves.

Additional categories could be added to define the more speculative category of "ultimate resource potential" or "technical potential" for geothermal energy. An ultimate resource potential or technical potential definition represents the amount of energy that would be possible to produce using all available or anticipated technologies and practices in all applications in which they could technically be adopted, and without consideration of costs or practical feasibility. For geothermal energy, the ultimate resource potential would be in the millions of megawatts. While this would be an impressive number, this cannot be used in any practical application and can be counter-productive because the impracticability of actual recovery at such scale engenders perceptions of impracticality of the geothermal resource, as a whole.

California Geothermal Basics

First, it's important to understand the general nature of the geothermal resource base in California. It is often considered to be geographically limited to relatively few areas of the state, which is not accurate. If you look at the two maps such as USGS Maps 1 and 2 in the Appendix,[8] you will see in the first that major geothermal production areas are concentrated in the North, South and East of the state. However, if you look at USGS Map 2, which shows where the presence of geothermal resources is indicated by heat flow or well data, the resource extends well beyond the major geothermal production areas. As shown by the red and purple dots (representing high temperatures) on Map 2, California's geothermal resource base is widespread. Except for the central valley, geothermal resources are present in every area of the state.

Comparing and Categorizing Recent Geothermal Estimates

There have been several recent estimates of geothermal potential in California. They lay the foundation for characterizing the potential contribution of the geothermal resource base, and the steps needed to realize that potential. For the purposes of this White Paper, we examined the following:

USGS Circular 790 - Assessment of Geothermal Resources in the United States

The USGS Circular 790 is recognized as the most thorough document assessing the potential of geothermal resources in the Untied States. Published in 1978, this report provides energy estimates for all identified geothermal resources believed to be hotter that 90°C. It gives power potential estimates for sites thought to be able to support geothermal power production. Resources considered developable for power production were assumed to have temperature above 150°C (Table 4 and 5, p. 44-57). Other tables list resources and sites with lower temperatures. (Note: in 1978 binary power plants, which can use lower temperature resources, were not considered feasible.)

USGS Circular 790 is available online at:
http://pubs.er.usgs.gov/pubs/cir/cir790#viewdoc

Petty 1992: Resource potential estimates referenced as Petty 1992 come from a report entitled "*Supply of Geothermal Power from Hydrothermal Sources: A Study of the Cost of Power in 20 and 40 Years*", (Petty S., Livesay B., Long W. & Geyer J., 1992, Sandia National Laboratory Report SAND92-7302)) This report provides 4 different power potential estimates for 51 sites corresponding to two different development timeframes (20 and 40 years) and high vs. low technology improvement assumptions. Values

provided in the spreadsheet correspond to the "Low potential estimate - 20 years" and "High potential estimate - 40 years" respectively.
Petty's report is available online at:
http://www.prod.sandia.gov/cgi-bin/techlib/access-control.pl/1992/927302.pdf

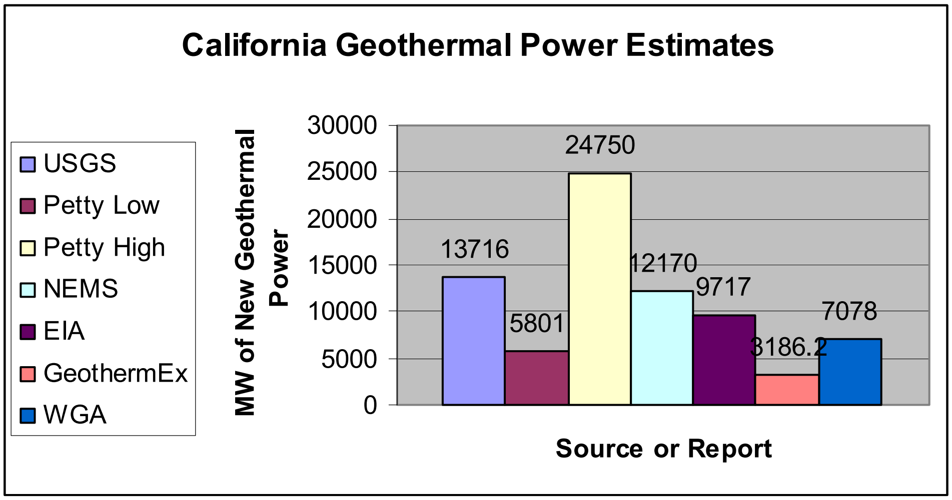
DOE Consultants Data and EIA data are used by the federal government for energy planning purposes. DOE data was extracted from the NEMS model and EIA data was used for the Annual Energy Outlook 2005 report. (This data is not available on-line, and was given to Nathanael Hance of GEA by these agencies for analysis conducted for the Department of Energy.)

GeothermEx-CEC: This set of data comes from "*New Geothermal Site Identification and Qualification*" prepared by GeothermEx Inc. (GeothermEx 2004) for the CEC and was released in April 2004. This report focuses on resources located in California and Nevada. This report as well as the underlying database is available online at:
http://www.geothermex.com/CEC_PIER.htm

WGA This data comes from the final report of the Geothermal Task Force of the Western Governors' Association's Clean and Diversified Energy Advisory Committee (WGA CDEAC), published January 2006 and available at www.westgov.org. On July 25, 2005, a group of 26 individuals with diverse expertise related to geothermal resources and geothermal power production participated in a workshop at the University of Nevada, Reno, to review and evaluate a compilation of historic and contemporary data. The workshop was facilitated under the auspices of the geothermal task force of the WGA Clean and Diversified Energy Initiative. The results of the workshop assessment of resource capacities are summarized as near-term potential/low cost (10 years and/or up to 8 cents/kWhr) and longer-term/higher cost (20 years and/or up to 20 cents/kWhr). The two figures were considered to be separate, and the total estimate presented is the sum of both.[9]

Figure 2 shows the total geothermal power estimates from each of these reports. As the figure shows, the range of estimates is substantial.

Figure 2: A Comparison of Geothermal Power Supply Estimates



Each of these studies deserves discussion, since each appears to produce an estimate at a different point along the reserve-resource continuum.

USGS: This 1978 assessment estimated that 90% of the geothermal resource base is undiscovered. The undiscovered resources are not included in Figure 2 above. Also, both the identified and unidentified resource estimates were "restricted to depths of less than 3km" (USGS, Circular 790, Page 31). The USGS did take into account some economic considerations by limiting the depth at which it felt resources were economically recoverable, for example, and it generally limited its resource identification to those with very high likelihood of potential development. Their estimate shown in Figure 2 would best be considered a conservative estimate of Probable Reserves above 3km under the definitions discussed earlier. The USGS is in the process of updating this assessment, and should release a new assessment in 2008.

GeothermEx: This is closest to a "reserve" estimate for California and nearby in Nevada from which transmission of power could potentially occur. The report assumes specific economic terms for production, requires that a minimum amount of work has already been done to identify the resource, incorporates considerations of transmission availability, and otherwise provides an estimate that can be accepted with a high degree of certainty. In terms of the resource categories discussed earlier, this work comes closest to being characterized as defining "Proven Reserves."

Petty, *et al*: These estimates are based upon the study "Supply of Geothermal Power from Hydrothermal Sources: A Study of the Cost of Power in 20 and 40 Years" by Susan Petty, B.J. Livesay, William P. Long, and John Geyer for Sandia National Laboratory, published in November 1992. This study represents a substantially different approach than that undertaken by GeothermEx. Their approach is explained in part as follows:

> *For resources where active exploration is not ongoing, we estimated the possible resource available in 20 and 40 years using first the USGS estimate, then published data, our own judgment and industry contacts. In cases where no USGS estimate has been made and little is known about the resource and no current interest has been shown in exploring it, we estimated that 25% of the total potential resource could be available in 20 years and 50% in 40 years.*
>
> *Another difficulty arose with the potential power from resources with temperatures between 110°C and 150°C. Exploration of these resources is at a standstill at present. There is little data available on most of them and the estimates of recoverable power made of USGS estimates of beneficial heat were extremely large. For estimates of the current exploration scenario we assumed that 25% of this very large resource base could be available in 40 years.*
>
> *Geothermal exploration has to date concentrated on the easy to find resources tied to some sort of surface manifestation such as a hot spring or recent volcanism. However, there should be many more resources as yet unidentified by*

either surface expression or current exploration efforts. It is important to make an attempt to quantify such resources since they may provide a long term, large electric power base. However, increased exploration would be needed to identify these resources.[10]

Based upon the description of the analytical process used, it seems that the Petty *et al* work would fall into the category of "Probable Reserves" although some sites appear to approach "Possible Reserves." It also appear that the estimates are curtailed significantly from what would be a total resource estimate, and overall have a better than 50% chance of achieving the level of energy production specified.

DOE NEMS and EIA AEO 2005: The data used in both the DOE National Energy Modeling System (NEMS) and EIA's Annual Energy Outlook (AEO) was made available to GEA for the process that resulted in the WGA workshop discussed below. The data presented represents the estimate from these two national sources. GEA's analyst, Nathanael Hance, expressed the view that the Petty assessment was in large part the basis for the estimates used by both DOE in the NEMS Model and the EIA's AEO, but each had made different changes and modifications. Discussions with DOE staff and consultants at the Princeton Energy Research Institute (PERI) supported this conclusion.[11]

WGA: The WGA Geothermal Task Force Report includes an extensive discussion of the development of its resource estimates. The following excerpt is from the Appendix to that report.

The Geothermal Energy Association (GEA) organized a workshop at the University of Nevada at Reno on Monday July 25, 2005 to review existing resource capacity potential and development cost estimates of known geothermal sites. The objective of this workshop was to provide updated information to the Western Governors' Association (WGA) Clean and Diversified Energy Initiative, notably by gathering data needed to build a geothermal supply curve.

Workshop participants reviewed resource capacity estimates of geothermal resources located in the western United States. The review targeted a list of existing sites based on the USGS Circular 790 (resources with temperatures nominally greater than 150ºC), a database from the Information Administration (EIA) of the U.S. Department of Energy, and a recently published "New geothermal site identification and qualification" (GeothermEx-CEC, June 2004). The review process considered two different values of a power potential for each site:

- *A first power capacity estimate cites new power capacity that is considered to be commercially attractive to be developed at each site within the next 10 years at a price of power up to 8 cents per kilowatt-hour (¢/kWh). This price excludes supplemental transmission costs, i.e. for tie-in carriers to transmission corridors.*
- *Second, the workshop considered resource power potential estimates that might be built at sites, using currently available technology, when price and timeframe constraints were relaxed. A nominal target power price limit was 20¢/kWh, and an approximate time frame of 2015 to 2025 was a basis for development projections.*

The methodology employed for the workshop to evaluate resource potentials was as follows: A set of spreadsheets listing existing site-specific resource potential values was circulated among workshop participants before the workshop for review and the source documents identified. During the workshop, the resource potential estimates were debated. Consensus was obtained for each site. In cases for which workshop participants provided a review for a site, the discussions began with this value. When a value was not available from the participants, the discussion began with the GeothermEx-CEC value. And last, the EIA and USGS values were used as a starting point for discussion when no reviewed or CEC data were available.

Where little information was available about individual resources, some sites were lumped together with a combined power capacity estimate (e.g. "Cascade volcanoes" or "other Nevada sites"). Some sites were removed from the list, which were considered not to be developable or the information was deemed otherwise not reliable.

Significantly, the second, longer-term power capacity values correspond to either (1) sites that would need more than ten years to be developed (even if power production cost could be lower than 8¢/kWh), or (2) sites that would be viable only at power prices above 8 ¢/kWh and up to about 20¢/kWh. Substantial uncertainty characterizes some resource estimates for sites where little exploration has been completed. Such sites would be commercially questionable development candidates within the 10-year (2015) time frame, as venture capital would be difficult to secure to fund the inherently risky exploration phase of development. These prospects would thus require added time to guide them through commercial proving and bring them online. Given the time needed to develop even proven geothermal resources (i.e. to secure leases, to obtain permits, and to confirm practically achievable power potentials), most projects now considered developable within the next 10 years are, in reality, already well-known resources.[12]

Based upon the description of the methodology in the WGA report, this appears to approach a Proven Reserve estimate, but given the uncertainties of the process used for the WGA estimates this estimate is probably best considered a "Probable Reserve" estimate from these sites.

Attached in the Appendix as Table 1, a detailed comparison of each of these studies shows their estimates on a comparative basis, site by site.

Cross Cutting Considerations: Each of these studies made different assumptions about the price at which geothermal resources would or could be developed, often reflecting the market expectations around the time the report was written. Given that this paper seeks to examine resource potential, choosing one set of market-parameters would be counter-productive to this effort by artificially limiting the results based upon highly volatile external factors and analytical assumptions about project costs.

Moreover, the levelized cost at which geothermal energy can be produced is greatly affected by non-market, non-resource factors such as permitting delays, industry growth rates, and financing options. Also, given the competition between geothermal developers and oil and gas developers for drilling rigs and equipment, the cost of geothermal development is highly dependent upon the status of domestic oil and gas markets.

A recent report prepared by GEA examines these variables, *Factors Affecting Costs of Geothermal Power Development*, by Cédric Nathanaël Hance, August 2005. This report details the variables that affect actual costs and concluded that the "levelized cost of geothermal power has a large range of variability."[13] The analysis finds that the cost of geothermal energy is highly dependent upon:[14]

1. The nature of the project *(greenfield vs. expansion)* and extent of exploration activities.
2. The size of the project (economies of scale)
3. The rock and resource characteristics affecting drilling costs,
4. The site accessibility, leasing costs, remoteness & topography (road and connection infrastructure),
5. The high financing costs (interest rates/ rates of return) related to financial risk,
6. Total delay time before the power plant is put online (e.g. permitting).

Most of these factors can be greatly influenced by federal and state policies, and are not inherent to the geothermal resource base. Any future examination of California's geothermal resource potential may also wish to examine how state and federal policies might positively influence geothermal energy's future contribution to the state.

California's Resource Potential

Geothermal Power's Potential

If by resource potential we mean "the amount of energy that can possible be produced using all available or anticipated technologies and practices in all applications in which they could technically be adopted, without consideration of costs or practical feasibility," then none of these seven studies appears to define California's geothermal resource potential.

Each of the studies examined above includes specific considerations of cost and technology among others. Moreover, none examine the broad areas of the state where geothermal resource is present as portrayed by USGS. To the contrary, each of these seven studies is based upon development at specific, identified sites as detailed in Table 1 of the Appendix. The USGS estimated in its 1978 report that 90% of California's resources were hidden, or as yet unidentified. Since that time, few new sites have been added to the list of identified resources and it appears that most of the resource still remains unknown.

There have been some estimates that look at a wider resource potential, and those indicate that the ultimate potential for geothermal energy in California could be substantially greater than these estimates.

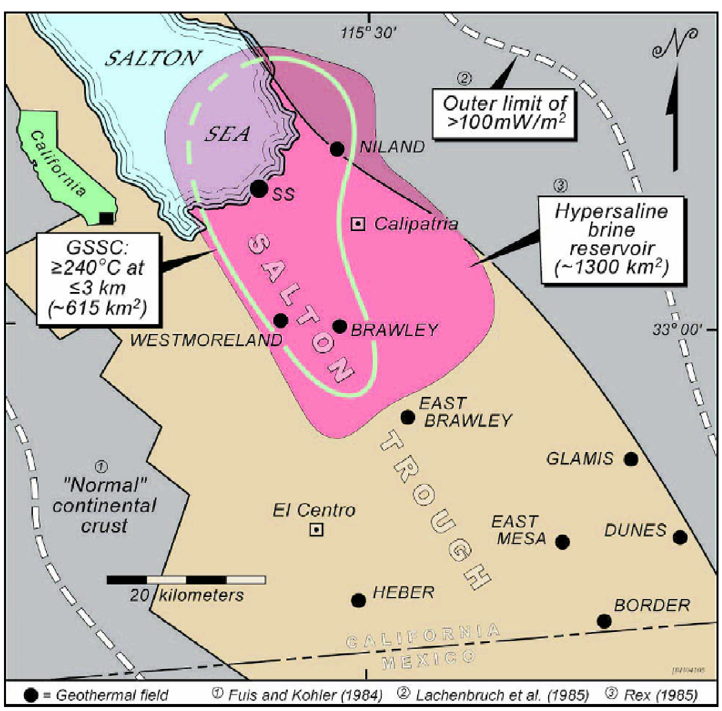
For example, in the November 13, 2002 Resource Evaluation for Salton Sea Unit 6 (by Steve Baker), the CEC staff compares the applicants estimates of "possible reserves of 2,300MW" with prior estimates by Union Oil. As the CEC paper notes, Union Oil's estimate of geothermal potential for the Salton Sea KGRA was "25,000 MW for 30 years."[15]

CEC goes on to state: "Staff believes the true capacity of the resource lies somewhere between these two estimates." This comment refers to the area within the Salton Sea Known Geothermal Resource Area (KGRA). There are six other KGRAs covering approximately 254,827 acres just in Imperial County

But, as expansive as the Union Oil estimate may seem for just this one KGRA, in 2005 the University of Utah's Energy and Geosciences Institute (EGI) went further in its report to the US Department of Energy, examining the potential of the Imperial Valley for enhanced geothermal production. The rationale for the study was, according to EGI, the fact that the Imperial Valley is unquestionably the Nation's premier high-temperature hydrothermal province with "enormous potential for conventional expansion" and "even greater scope for Enhanced Geothermal System (EGS) commercialization."[16]

The area EGI examined encompasses more than the Salton Sea KGRA. Their study area was called the "Greater Salton Sea Geothermal Cluster" (GSSC) and covered an area of some *615* km^2 shown below (or 146,100 acres):

Figure 3: The Greater Salton Sea Geothermal Cluster[17]



According to EGI, "*within this area heat was present everywhere ≥240°C (464oF) at ≤3 km depth. Just a 2-km slice of the GSSC could yield as much as **5,850,000 MW-Years of thermal energy, or* ***<u>820,000 MW-Years of electricity.</u>***"

> According to Jeff Hulen of EGI, *"A skeptical person might say something like "Why, there's that much heat theoretically available in any number of places (e.g., The Geysers, Medicine Lake) in California. What makes the Salton Sea area so special?"*
>
> *The answer goes like this: In addition to heat, porosity--as well as hot water filling and circulating in that pore space-- is fundamentally required for a viable geothermal system. In almost all cases, a geothermal system or heat anomaly will occur in fractured igneous or metamorphic rocks (for example, granite and gneiss), in which bulk porosity (potential hot-water storage and fluid-flow space) seldom exceeds 2% (generally less). By contrast, the rocks of the Salton Sea geothermal cluster (indeed, of the entire Salton Trough) are overwhelmingly sedimentary in origin (sandstone, siltsone), very similar to the rocks of a typical oil or gas field. Porosities in these sedimentary rocks, even where they are unfractured, typically range from 10-30%. This higher porosity translates directly to higher fluid volume in the rock*
>
> *As an example, the exemplary 2-km slice of the greater Salton Sea geothermal cluster would have a bulk hot-water volume of 26.6* km^3 *(and probably less) if the reservoir rocks were igneous and metamorphic like a typical "Basin and Range" geothermal system. Because it has sedimentary reservoir rocks, the GSSC likely has a bulk hot-water volume of 133* km^3 *to 399* km^3*. Because of this fact, truly "dry" geothermal wells have been a rarity here. On the contrary, most of these wells have yielded hot waters and brines at commercially acceptable flow rates and temperatures. The GSSC and much of the entire Salton Trough represent a*

truly vast reserve of renewable geothermal energy that is currently producing at only a small fraction of its ultimate practical potential.[18]

The conclusion of EGI that there will be a high likelihood of success when using EGS techniques to stimulate production in sedimentary systems is shared by others, including Dr. David Blackwell of Southern Methodist University. Dr. Blackwell is looking at co-producing geothermal power from the hot water that is produced at oil and gas wells. Substantial amounts of hot water are produced in many oil and gas environments. Further, Dr. Blackwell believes that these sedimentary basins are highly conducive to EGS techniques, and that this has been demonstrated by the oil and gas industry in many areas.[19]

EGI presented to DOE a geothermal production goal that it felt was reasonable to pursue for the GSSC. They proposed to DOE that “multiple new EGS and natural hydrothermal targets” in the GSSC could produce a viable geothermal resource producing 40,000 MW by 2040.

If a combination of advanced technology and aggressive development could produce a potential contribution of 40,000 MW in this area of the state, what does this mean for the total geothermal potential of California? Obviously, the technical potential for geothermal energy production in California under these assumptions is far greater than the 7,000 MW estimate of the WGA working group, and surpasses even the nearly 25,000 MW projected by Petty et al. This, however, assumes the technology to engineer production from geothermal systems is developed and applied at sufficiently low costs.

Direct Use Geothermal Resources

So far the discussion has focused almost entirely on electricity production from geothermal resources. However, significant energy needs could be met through direct uses. Geothermal heat can be used in buildings, greenhouses, spas and other traditional “direct use” facilities instead of fossil fuels or electricity. With a growing demand for alternative fuel production – ethanol and hydrogen – geothermal resources can also play a major role in providing the energy needed for the energy-intensive production processes behind these new fuels. Energy costs for alternative fuel production are a major issue, and other alternatives – such as increased use of coal – have serious environmental drawbacks.[20]

CEC recently funded an assessment of California's direct use geothermal potential. That report, by Science Applications International Corporation (SAIC), said in part:

California has significant geothermal resources throughout the state. Almost 1,000 thermal wells and springs, more than 900 low-to-moderate temperature geothermal resource areas and over 100 direct-use sites have been identified in California. [9] Six percent of the state's electricity is supplied by geothermal power plants using high-temperature resources. The Geo-Heat Center in the Oregon Institute of Technology states that there are nearly 1,500 potential geothermal well sites located within five miles of towns and medium-sized cities in the western U.S. Low-to moderate temperature resources have an energy base of 38,900 quads (a quad is 1015 Btu) compared to high-temperature geothermal resources which have a resource base of 4,800 quads in the US. [8] A list of all known geothermal resources in California is included in Appendix 3.

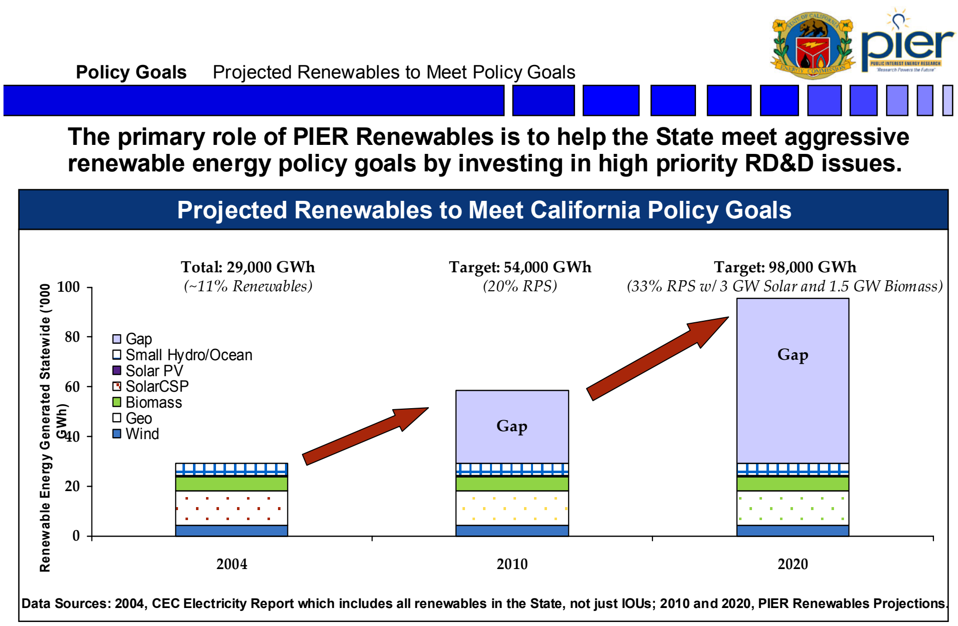
While the SAIC report does not provide a direct use resource estimate for the state, it does demonstrate the widespread nature of the resource available. Appendix 3 of SAIC's work has more than 25 pages listing, single space, geothermal wells throughout the state.

Realizing California's Geothermal Potential

Including the roughly 2,000MW of geothermal power on-line today, it appears that the available data would indicate that California's geothermal reserves could produce between 5,000 and 25,000 MW, depending upon different economic, policy, and timeframe assumptions. The total potential of the resource base is likely to be significantly greater. If the USGS' estimate that 90% of the resource base is undiscovered is considered, the total geothermal resource potential of California's geothermal resources would exceed the total current generating capacity of all three of the state's investor owned utilities, some 42,000 MW.[21]

California needs to bring significant new renewable energy production on-line. As Figure 4 shows, there is a significant gap in the availability of economically viable alternatives that geothermal energy could help fill.

Figure 4: California's Renewable Power Gap



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What can be done to bring this tremendous energy potential to the point that it can meet the needs of Californians? To begin with, the existing "system" is not working effectively to do so in terms of providing financial support, encouraging exploration, and producing basic resource data. These might be seen as separate but intimately interrelated factors, but they are inseparable in practice.

If the financial returns for producing geothermal energy were sufficient, industry would explore for and develop new geothermal resources. This appears to be the fundamental assumption of energy policies. Both under the Public Utilities Regulatory Policies Act of

1978 (PURPA) and the current Renewable Portfolio Standard (RPS), the presumption seems to be that offering contracts will attract bidders. But is that sufficient?

An underlying assumption is that the geothermal industry can undertake the exploration necessary to define the known resource base with more precision. In California, some exploration has been supported by the state's Geothermal Resources Development Account (GRDA). GRDA provided the Fort Bidwell Indian Tribe and Mammouth Pacific Corporation with funds for exploration in 2006. In previous years, it has funded such work at Four Mile Hill, Truckhaven, and other areas.

The US Department of Energy has funded exploration through its Geothermal Resource Exploration and Definition (GRED) program. As explained in the CEC staff paper, "Initiated in 2000, Geothermal Resource Exploration and Definition (GRED) Program is a cooperative Department of Energy (DOE)/industry effort to find, evaluate, and define additional geothermal resources throughout the western United States. To help mitigate a portion of the initial risk associated with the exploration and definition of geothermal resources, DOE provides up to 50% cost sharing (with early rounds providing projects up to 80% of project costs). The DOE and its laboratories also provide technical oversight and monitoring."

So, what are the problems?

First, exploration of new geothermal sites is expensive. Industry will typically spend funds only where it has first secured the rights to develop the resources. This means a company has acquired rights to private land or federal or state leases. With no new leasing available in California in well over a decade, industry is reluctant to spend upwards of $3 million per site on initial exploration where the lease necessary to develop the resource might never be obtained.

Second, there is little federal support or funding for the Bureau of Land Management (BLM) to undertake the relatively time consuming and expensive actions needed to approve new leasing. At the 2005 CGEC Summit, Sean Haggerty, BLM representative, stated that he couldn't answer definitively, but estimated that an Environmental Impact Statement (EIS) would require 12-18 months. This assumed that funding would be available to perform the assessment, which is not necessarily the case since funds are limited.[22]

Also at the 2005 Summit, Jim Lovekin opined that the key for new development outside of KGRA's was to "get a champion to work the system." [23] Lovekin explicitly recognized that this means having someone who holds the rights through ownership or a lease to develop the land with both the interest and ability to do so. But, in California on federal lands, where no leases have been issued in 20 years, that becomes nearly impossible.

Third, as a result of the preceding barriers, financial sources find little encouragement to take on the economic risks of supporting prospective development projects.

There was one rather direct discussion of these issues recorded in 2004, at a meeting sponsored by the National Geothermal Energy Collaborative (NGEC). The transcript of the meeting states:

> ***Challenges***
> *Rich Estabrook (BLM-CA) presented California's recent challenges with pending lease applications in Southern California. These included high costs and long time frames associated with completing adequate pre-lease NEPA documentation (conservatively, an EIS may cost $600,000 and take two years to complete. Most of the lease applications in California are within the California Desert Conservation Area, which raises the visibility of leasing and, therefore, would require an EIS before leasing could occur). It is anticipated that two EIS's would be needed to cover the high priority lease application areas. Another challenge is a lack of committed staff to process and manage leases (often staff is pulled off for litigation defense activities), lack of geothermal specific funding, and the expectation of litigation.*[24]

The NGEC discussion continued to delve into the problem. It was noted in the discussion that the cost to conduct the EIS documentation for just three of California's pending lease areas would be $1.5 million (Deep Rose, Truckhaven and Superstition Mountain). BLM officials indicated that "to justify spending the money, the return on the resource needs to be substantial." The view was also expressed that "agencies lose money in processing applications."[25]

So, we have a built-in feedback loop that effectively stalemates geothermal development: without leases, industry will not spend the millions of dollars needed to do basic exploration to understand and help characterize the resource better. And, without better resource characterization, the agencies had little incentive to propose or process new leases, which would cost large sums of money and have very uncertain returns.

A recent report by the US Government Accountability Office (GAO) also examined the problems facing geothermal development. The GAO found:

> *The risks and high initial costs associated with geothermal development limit financing and make financing more difficult. Energy consultants told us that few companies, including venture capitalists, are willing to provide funding for geothermal projects, particularly for the initial phases of exploration and confirmation. Industry officials who do provide funding for geothermal development told us that they would only fund projects that are either fully confirmed or are in areas of well-known geothermal potential. Even when fully confirmed, moreover, few lenders will finance a geothermal project until a contract has been signed by a utility or energy marketer to purchase the expected electricity. Geothermal industry officials describe the process of securing a contract as complicated and costly, especially for small geothermal developers who are generally unfamiliar with the various bidding mechanisms that utilities use to establish electricity prices. Officials with a large utility expressed their reluctance to purchase more costly electricity from geothermal plants and cited*

an inability to pass on the additional cost to ratepayers. Electricity from geothermal resources may also be unavailable during time frames specified by the contract because of delays due to environmental litigation or lack of available transmission. In addition, an energy consultant told us that most utilities are unfamiliar with geothermal resources, and they are unlikely to invest the necessary time to assess geothermal projects because geothermal electricity would make up a small percentage of their total energy portfolio.[26]

Contrary to the assumption cited above concerning market drivers, under the conditions described by the GAO Report, it would not appear likely that the market place, working by itself, will move the large geothermal resource to market. And, based upon the NGC workshop, it does not appear likely that the federal government will support major new leasing without first confirming that there is major new energy potential present. It would appear that a new approach is needed to realize California's geothermal potential in the near term. Without a new directive, the stalemate between government and the marketplace will lead to little new geothermal development outside of the already identified and leased or owned areas.

An Alternative Approach in Nevada

In Nevada, industry, government and academia have launched a cooperative effort to define and develop their geothermal resources. The following is taken from a statement signed by leaders in each sector outlining their initiative:[27]

GEOTHERMAL RESOURCES IN THE GREAT BASIN: RENEWABLE ENERGY SOLUTIONS FOR A RAPIDLY GROWING REGION

A Statement from Industry, Academia and Government Researchers and Practitioners

We need to institute a major effort to locate and define geothermal resource sites in order to accelerate the development of geothermal energy in the Great Basin. The challenges will be first to enhance exploration technologies and use them so as to minimize the future need for governmental financial support of high risk resource location and definition, and second to improve well siting to increase success rates and reduce drilling costs. Significant breakthroughs are required to enhance exploration technologies sufficiently to reduce the high risk of resource location and definition. Our goal is to enable industry to bring "One thousand megawatts on-line by 2017," potentially attracting new industry, increasing jobs, diversifying the economy and increasing tax bases, making geothermal a more effective contributor to the energy portfolio of western states.

How to Achieve Goal: *An informal consortium is being formed of major stakeholders to partner and collaborate in order to accelerate research and development efforts and assist in target definition to reduce the risk of well siting. Reduction of risk is expected to stimulate the geothermal industry towards meeting our power goal. Multiple stakeholder involvement is required to leverage each organization's strengths and fulfill the energy concerns of multiple states in the Great Basin region.*

Benefits*:*

- *Stimulate a multi-billion dollar private sector investment in bringing geothermal power on-line*
- *Help to meet the Nevada and California Renewable Portfolio Standards*

In Nevada, this statement proposes a collaborative government-industry effort with more direct involvement in defining the resource base and reducing development risk. This approach serves the needs of both the state and developers. If additional resources are not identified, and the risks of their development not reduced, Nevada would have difficulty reaching it RPS goals.

California, like Nevada, faces a fundamental problem with resource identification and development risk. The Nevada approach is something California may wish to consider: establishing a government-industry collaborative effort to define resources sites and accelerate development, setting goals for geothermal development tied to the state's RPS goals, and recognizing the need to accelerate research and development efforts.

This approach offers a way around the current impasse with geothermal resource exploration and development in California. The current stalemate between government and developers could be replaced by a collaborative approach that would allow California to develop it substantial geothermal resources in a manner that will support the state's climate and renewable energy objectives.

Proposal for a California Geothermal Development Plan

The California Geothermal Energy Collaborative (CGEC) brings together industry, federal and state government agencies, public interest representatives, and others into a forum and process that seeks to achieve consensus actions to promote geothermal use and development in the state. The CGEC could be the vehicle to develop a plan to move forward more aggressively with the fundamental issue – defining and characterizing California's geothermal resources.

This should involve not only industry and federal and state agencies that deal with leasing and resources, but also research and development experts who can apply advanced geothermal techniques to produce greater amounts of energy from high potential resource areas. California has some of the leading laboratories working on new exploration technologies and techniques for exploration and development that should be enlisted to help develop and define options to apply these new advances in geothermal energy to achieving California's renewable energy goals.

The expectation would be that the CGEC could formulate a working group to develop several approaches to public-private collaboration. The CGEC working group could then define the benefits, costs, and expected results from each approach in order to develop a "preferred" proposal that could be taken forward to CEC, the PUC, US DOE, the USGS, industry and others for discussion and hopefully support. Let's call that proposal a California Geothermal Development Plan (CGDP), and it is expected that production and preparation of that plan would take the cooperation and resources of both state and federal agencies as well as the California geothermal community. And, it's interesting to note that in less than a year after being initiated by Governor Schwarzenegger, the state's Biomass Collaborative spearheaded a multi-agency effort to produce a statewide biomass development plan.[28]

In order to lay a foundation for this activity, we must understand and characterize the resource better, and recognize the potential issues, impediments, and advantages to development in different areas of the state. A CGDP would provide the state agencies with better information about the resource base of the state and would identify the action needed to meet future goals. Also, identifying high priority areas for development could facilitate federal and state leasing and permitting, transmission planning, and other activities.

Through a CGDP, CGEC could help address the following additional questions:

1. What degree of exploration, including drilling, would be necessary to define the resource base? What would this cost, and who should conduct this work? To what extent can the cost and risk of project development be reduced, and at what cost in terms of exploration?
2. Would the cost of a collaborative effort be returned through higher bonus bids? Higher royalties? Expanded geothermal production? Power purchase agreement awards? Environmental benefits? How do we define these trade-offs?
3. Should the plan target prime areas of the state, where the resource values appear highest and conflicts least? Or, should the plan develop a better statewide assessment? Is there a way to "triage" how the plan's efforts are applied?

4. Does the assessment examine direct use potential? Distributed generation? What does it assume about geothermal power production economics and technology?
5. What role can advanced exploration techniques play in reducing costs or expanding coverage of an assessment? Can the effort be used to simultaneously test new exploration technology or techniques?
6. Can EGS techniques play a role in reducing the risk of successful development and where? Should areas be designated as EGS target areas and receive supplemental support?
7. Could the results of collaborative exploration be used to identify sites for preferential leasing and permitting? Would BLM and the state be able to fast-track leasing or permitting actions for high priority areas that were identified?
8. How could resource identification integrate with transmission planning for both the near and long-term? Does the potential for larger resources change options that would be considered for transmission? What actions are needed to ensure transmission is built to accommodate expected resource capability?
9. Are the traditional PURPA and RPS approaches to developing resources and issuing contracts appropriate? Does a development plan allow alternative approaches to development, and where would they be preferred?
10. Would development of a collaborative assessment allow pre-screening of environmental and other land use conflicts? Could the plan supplement federal, state or local planning requirements in a way that facilitates appropriate development and addresses higher goals such as national security, environmental quality, or global warming?
11. Who needs to be involved in the planning process directly or indirectly? Developers, operators, academia, national laboratories, Indian tribes, federal, state and local agencies, elected officials? What are their roles, and how can the CGEC engage them in this process?

The Steering Committee of the California Geothermal Collaborative met to discuss an earlier draft of this paper and these questions on September 11, 2006. That discussion focused on several steps that the CGEC, through its committees, could take. Based upon that discussion, I would recommend four next steps:

1) Establish a Resource Base Working Committee to improve our understanding of the resource base and to define what steps could be taken. For example, heat flow mapping of California is lacking and might be a relatively cost-effective approach to expanding resource knowledge and reduce development risk. Also, collecting relevant soil and water chemistry data from different sources in the state could be a valuable undertaking. This group could discuss how to integrate and prioritize these efforts, and work with CEC and the USGS to ensure synthesis of this information into improved resource assessments. The working group could discuss these and other approaches to improving resource assessment and support and augment the work being undertaken in the near term.

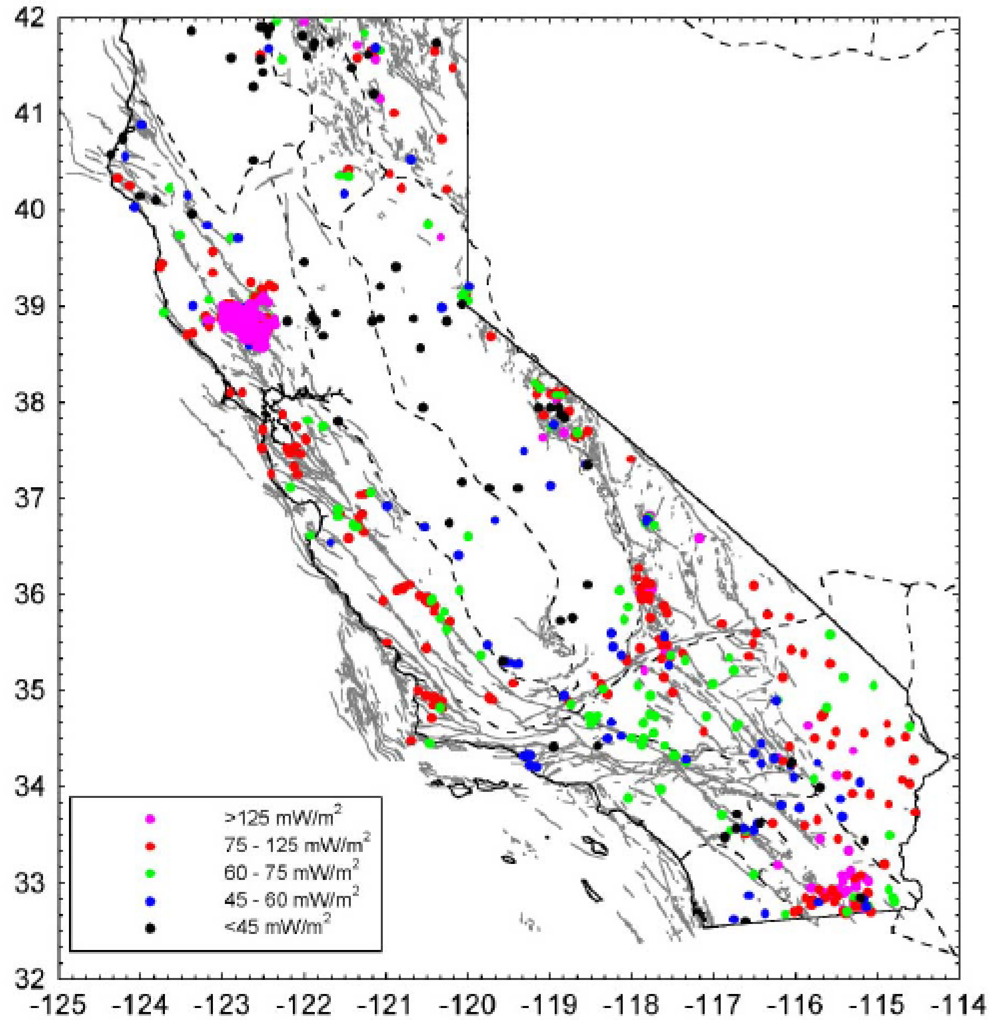
2) Establish a special Greater Salton Sea Geothermal Task Force to examine how to realize the potential of the Greater Salton Sea area and define the initiatives that California might consider to encourage development in this region. This group would examine the full range of obstacles to development of the resources in the region, from leasing and permitting to power purchase agreements and transmission access. It should also work with the Resource Base Committee to better define the resource potential from this region, including application of new technology to enhance geothermal production.

3) Convene a statewide Direct Use and Small Power Production Workshop to expand our understanding of the potential for these technologies to contribute to California's energy needs, and assess how their development and use will change our understanding of the resource base and both where and how it can be utilized. Also, follow-up on previous recommendations made to CGEC to expand our knowledge of direct use in the state, share success stories, and develop outreach and marketing mechanisms, such as the Green-G certification.

4) Prepare a report with specific recommendations for consideration by the CEC examining what could be accomplished by undertaking more formal state action, including development of a Geothermal Development Plan. This should examine the success of the state biomass plan and similar initiatives, and discuss with stakeholders in Nevada their efforts. The report should include consideration of requesting that the Governor direct state agencies to prepare a formal statewide Geothermal Development Plan, and outline the pros and cons of such an action as well as the benefits to the state from expanded geothermal energy production and use.

USGS Map 1


GM
SV
LASSEN
AL
GREAT
BASIN
GEYSERS
SIERRA NEVADA
GREAT CENTRAL VALLEY
LV
COAST RANGES
DEATH
VALLEY
COSO
MOJAVE
BLOCK
TRANSVERSE RANGES
PENINSULAR
RANGES
IMP
VALLEY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75 - 125 mW/m2
60 - 75 mW/m2
45 - 60 mW/m2
<45 mW/m2
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TABLE 1: Detailed Comparison of Geothermal Resource Studies

	USGS Circular 790 (MW)	Petty 1992 Low (MW)	Petty 1992 High (MW)	DOE Consultant's Data (MW)	EIA-AEO2005 Data (MW)	GeothermEx-CEC Most-likely (MW)	WGA 2006 Combined
CALIFORNIA							
Border	31						30
Brawley	640	150	640	600	600	326	738
Buckeye HS	90<T<150°C	250	1270	985	985		
Calistoga	90<T<150°C					25	30
Clear Lake Volcanic Field area	900	500	900	900	400	43	70
Coso area	650	650	1000	750	495	75	225
Dunes	90<T<150°C					11	10
East Mesa	360	360	500	460	326	86	150
Glamis	90<T<150°C	275	680	680	680	6.4	10
Heber	650	250	500	350	213	42	70
Honey Lake & Wendell & Amidy						7.1	20
Kelly HS	90<T<150°C	300	3000	1740	1740		10
Lassen	National Park - Vapor dominated	116	350	350	350		
Long Valley (HT)		500	1600	200	200		360
Long Valley caldera (LT)	2100	250	750	200	150	71	
Medicine Lake		500	3000	400	153	304	960
Morgan Springs-Growler Springs (includes parts of Lassen not in Park)	116						50
Mount Signal						19	50
Niland						76	225
Randsburg area	84	25	250	250	250	48	50
Salton Sea area	3400	500	3000	1500	407	1400	2860
Sespe HS	90<T<150°C	125	660	555	555	5.3	
Sulphur Bank Mine (Hot Bolata)	75					43	
Superstition Mountain						9.5	50
Surprise Valley / Lake City	1490	250	1490	850	850	37	75
The Geysers	1610					550	450
Wendell	90<T<150°C	250	650	650	613	1.9	
Westmorland	1710	50	1710	350	350		150
Wilbur HS	90<T<150°C	500	2800	400	400		
Truckhaven							75
Mount Shasta							360
TOTAL California	***13716***	***5801***	***24750***	***12170***	***9717***	***3186.2***	***7078***

Endnotes/References:

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[2] *Reserves And Resources, Supply And Demand: Why We Need Credible Resource Assessments*, By Naresh Kumar, Ph. D. Vice Chairman, Committee on Resource Evaluation, American Association of Petroleum Geologists, Testimony Presented to the United States House of Representatives, Subcommittee on Energy and Mineral Resources, March 22, 2001, Washington, D.C.
[3] Ibid.
[4] (http://www.ncpa.org/pub/bg/bg159/)
[5] Colin Williams, USGS, Presentation to the California Geothermal Summit, May 2005
[6] All three definitions are adapted from Wikipedia definition http://en.wikipedia.org/wiki/Oil_reserves#Definition_of_Oil_Reserves
[7] While more conventional definitions are available, the author found the Wikipedia approach more appropriate for purposes of sought by this paper, ie to use a definition that clearly highlights the critical issues to policy makers.
[8] From Colin Williams, USGS, Presentation to the California Geothermal Summit, May 2005
[9] At a May 2006 workshop on geothermal resources sponsored by NREL, the question of whether these two figures should be combined into a larger total was raised, and the consensus of the participants was that they should be added together for a total potential resource figure, private communication, Bruce Green, NREL.
[10] "Supply of Geothermal Power from Hydrothermal Sources: A Study of the Cost of Power in 20 and 40 Years" by Susan Petty, B.J. Livesay, William P. Long, and John Geyer for Sandia National Laboratory, published in November 1992, page 8.
[11] Personal communication, Dan Entingh, PERI and Tom Petersik, DOE-EIA.
[12] *Geothermal Task Force Report* to the WGA Clean and Diversified Energy Advisory Committee, January 2006, http://www.westgov.org/wga/initiatives/cdeac/geothermal.htm pages 55-56.
[13] *Factors Affecting Costs of Geothermal Power Development*, by Cédric Nathanaël Hance, August, 2005, page 4, available at: http://www.geo-energy.org/publications/reports.asp, page 3.
[14] Ibid. page 12. Also see Appendix G for a chart showing each of these factors by stage of development with an indication of their relative importance to the final levelized cost of the project.
[15] SALTON SEA UNIT 6 PROJECT GEOTHERMAL RESOURCE EVALUATION, Steve Baker, California Energy Commission, November 13, 2003
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[26]"Increased Geothermal Development Will Depend on Overcoming Many Challenges," US GAO, May 2006, GAO-06-629
[27] Document received from Dan Shochet, Ormat Nevada
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