Geothermal Working Group Report

Evaluating geothermal energy as the primary resource for baseload power in the County of Hawaii

01 January 2012

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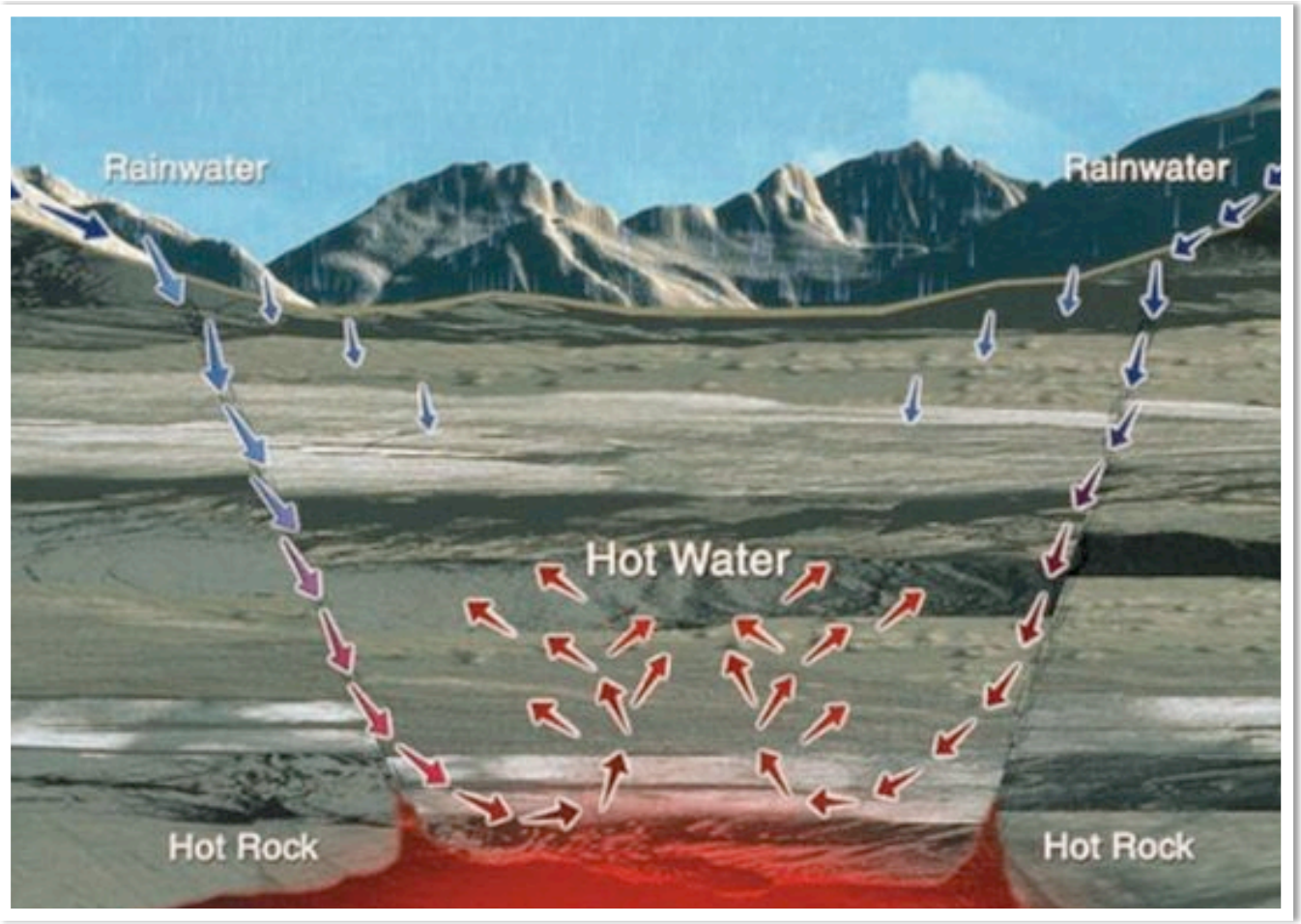

Natural geothermal reservoir

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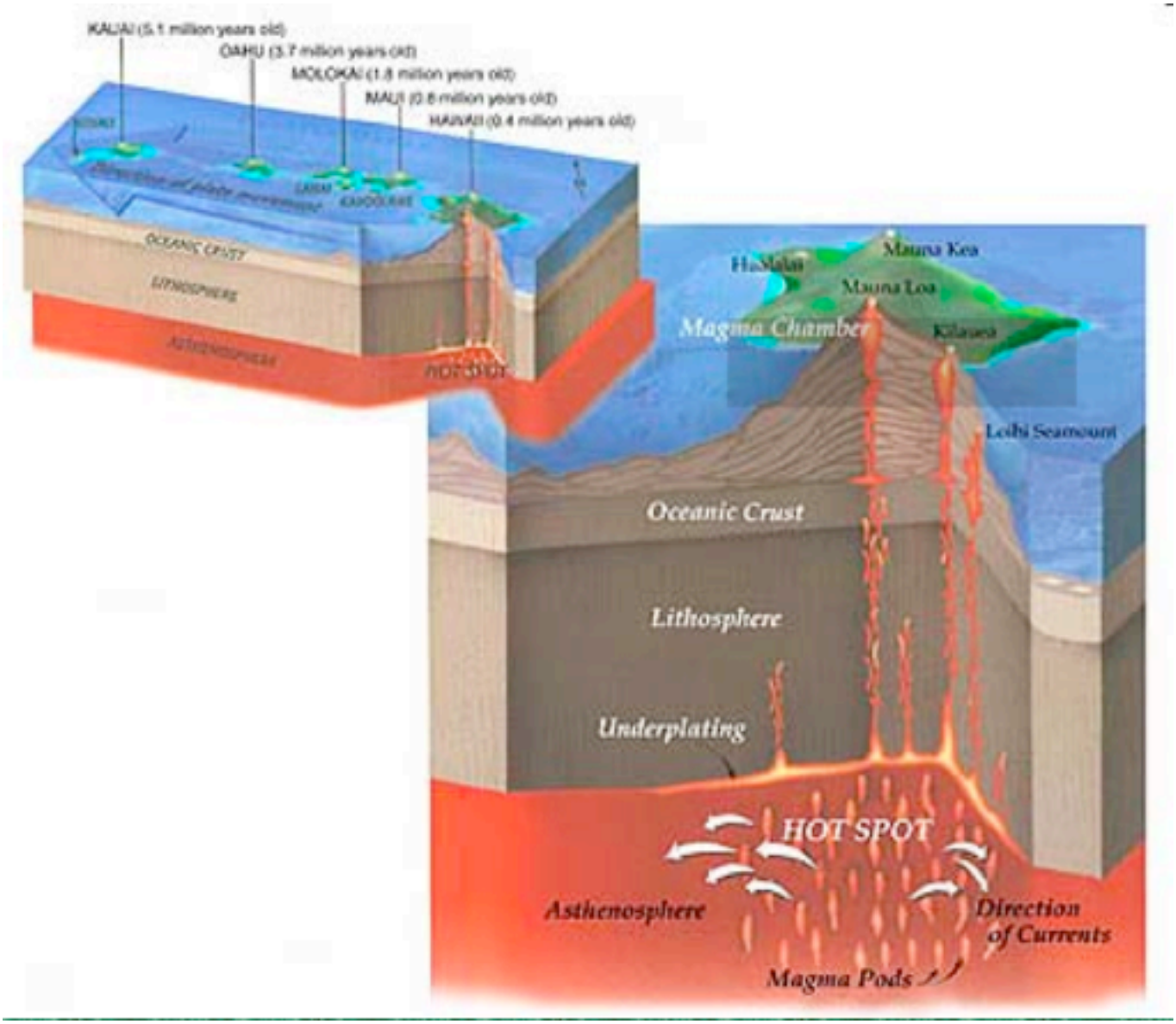
I. Executive Summary

SCR 99 established the Geothermal Working Group to evaluate geothermal energy as the primary source of baseload power for electricity in the County of Hawaii. An analysis of technical data and of expert testimony provides convincing rationale to develop local renewable energy plants and transition away from the county's dependence on petroleum-fueled generators for baseload electricity. Each stage of development must consider public safety and environmental concerns. Funding for research is required to ensure that the transition never harms people, property, or wildlife and that a robust and reliable supply of energy is always available. It is critically important to the welfare of all Hawaii residents that we begin to develop local energy immediately.



Hawaii's geological access to Earth's energy

The Geothermal Working Group's principal findings:

- Geothermal is a renewable resource indigenous to the island of Hawaii that is dissociated from the price volatility of petroleum fuels.

- Geothermal can be a key component in a diversified energy portfolio for Hawaii County, both for the electrical grid and for transportation.

- In Hawaii, geothermal is a firm-energy resource at lower cost than fossil fuel.

- Developing multiple geothermal plants is the most prudent approach.

- Geothermal has the potential to supply baseload electricity; long term reliability and the ability to supply grid management services (currently supplied by conventional fossil-fueled power plants) must be demonstrated in order to consider geothermal as the primary energy resource.

- With geothermal power plants, agricultural fertilizers, hydrogen, oxygen, and business-enterprise power can be produced for off-peak rates during the hours of curtailed electrical demand.

Charging station for electric vehicles

II. SCR 99 and Corresponding Report Sections

BE IT RESOLVED *by the Senate of the Twenty-fifth Legislature of the State of Hawaii, Regular Session of 2010, the House of Representatives concurring, that the County of Hawaii is requested to establish, convene, and facilitate a working group to analyze the potential development of geothermal energy as the primary energy source to meet the baseload demand for electricity on the Big Island*

See:
Appendix A Senate Concurrent Resolution 99, Sponsor: Russell S. Kokubun
Appendix B Composition of the Working Group
Appendix C Geothermal Working Group Minutes

BE IT FURTHER RESOLVED *that the working group consist of eleven members with the Mayor of Hawaii County designating the chairperson, including:*

The Hawaii County Energy Coordinator, or designee;
One member designated by Hawaii Electric Light Company;
One member designated by the Big Island Labor Alliance;
One member designated by the Hawaii Island Economic Development Board, Inc.;
One member designated by the Chairperson of the Public Utilities Commission;
The Hawaii Island Office of Hawaiian Affairs Trustee, or designee;
One member designated by the Director of Business, Economic Development, and Tourism;
One member designated by the Chairperson of the Board of Land and Natural Resources;
One member who is a representative of a non-profit, environmental group to be selected by the President of the Senate;
One member who is a representative of a cultural organization to be selected by the Speaker of the House of Representatives; and
One member representing West Hawaii to be selected by the Mayor of Hawaii County;

See:
Appendix B Composition of the Working Group

BE IT FURTHER RESOLVED *that the working group consider the potential impacts of expanding geothermal energy production on native habitats, pristine forest environments, and native Hawaiian values and practices, and recommend mitigative measures to ameliorate any adverse impacts that may be caused by geothermal energy production expansion*

See:
Environmental Impacts

BE IT FURTHER RESOLVED *that the working group also consider what improvements may be required for the electricity transmission system and what funding may be available for such projects from the United States Department of Energy*

See:
Infrastructure and Engineering Considerations

BE IT FURTHER RESOLVED *that the working group is requested to include a feasibility and cost-benefit analysis of using geothermal energy as the primary energy source to meet baseload demand on the Big Island, including an analysis of community, environmental, and economic benefits*

See:
The Cost of Energy
Community Benefits
Royalties Disbursement

BE IT FURTHER RESOLVED *that any community benefits analysis include the possibility and feasibility of establishing a community benefits package that includes the distribution of royalties derived from geothermal energy production to impacted communities, and strategies to avoid passing costs onto the customer*

See:
Community Benefits
Royalties Disbursement
Appendix D Activities to Date
Appendix L Warranty Deed and Grant of Access Easement, July 11, 2006
Appendix M Memorandum of Agreement Between the Department of Land and Natural Resources, State of Hawaii and the Office of Hawaiian Affairs

BE IT FURTHER RESOLVED *that the working group is further requested to include a detailed accounting of the geothermal royalties collected by the State, the County of Hawaii, and the Office of Hawaiian Affairs, including how those entities distribute and use the royalties*

See:
Royalties Disbursement

BE IT FURTHER RESOLVED *that the County of Hawaii is requested to provide an interim report to the Legislature no later than twenty days prior to the convening of the 2011 Regular Session, and the final report of the working group to the Legislature no later than twenty days prior to the convening of the 2012 Regular Session*

See:
Geothermal Working Group Interim and Final Reports

BE IT FURTHER RESOLVED *that certified copies of this Concurrent Resolution be transmitted to the Governor, the Chairperson of the Board of Land and Natural Resources, the Director of the Department of Business, Economic Development, and Tourism, the Chairperson of the Office of Hawaiian Affairs, the Mayor of Hawaii County, the Chairperson of the Hawaii Island Economic Development Board, Inc., the Chairperson of the Public Utilities Commission, the President of the Hawaii Electric Light Company, and the President of the Big Island Labor Alliance*

Coordinated through Hawaii County Mayor's Office Administrative Services

Hawaii's geothermal power plant produces 30 megawatts of power

Overview

Geothermal energy can be developed to become the cheapest form of baseload power for Hawaii County. There are no importation or storage costs. Using geothermal as the primary source of baseload power will permit the county's businesses to be more competitive with the rest of the world. Using geothermal as the primary source of baseload power will also help folks on the lowest rungs of the economic ladder—those who struggle with the cost of services.

In addition to stability and affordability, geothermal can leave less of an environmental impact than the commercially-available baseload power sources of electricity. There are no greenhouse gases, emissions and no oil spill risks.

The lower rates of off-peak geothermal electricity encourage the production of ammonia locally. Ammonia is an efficient hydrogen carrier that can be used to power internal combustion engines and as an aid to local agriculture as fertilizer. Light-industry business parks constructed near geothermal energy plants can use excess heat as a resource for heating vegetable and tropical flower hothouses, drying wood, and drying fish.

Benefits of geothermal energy to the community include sharing in geothermal royalties. In accordance with state law, the geothermal royalties are paid directly to the Department of Land and Natural Resources who allocate the royalties in three ways:

1. Department of Land and Natural Resources receives 50%
2. County of Hawaii receives 30%
3. Office of Hawaiian Affairs (OHA) receives 20%

Potential adverse impacts are listed below:

- Interference with worship of the Goddess Pele
- Interference with certain Native Hawaiian practices
- Rainforest destruction
- Possible health and safety impacts
- Disruption of the way of life for nearby residents
- Hydrogen sulfide and other air quality issues
- Noise
- Increased strain on an inadequate infrastructure
- Impact on native fauna and flora

The amount of geothermal royalties paid to the State of Hawaii fluctuates each fiscal year, since power output and sales to HELCO vary.

FISCAL YEAR	TOTAL	STATE OF HAWAII	COUNTY OF HAWAII	OFFICE OF HAWAIIAN AFFAIRS
1995 & PRIOR	$788,611.86	$394,305.93	$236,583.56	$157,722.37
1996	$499,353.00	$249,676.50	$149,805.90	$99,870.60
1997	$546,431.00	$273,215.50	$163,929.30	$109,286.20
1998	$522,235.00	$261,117.50	$156,670.50	$104,447.00
1999	$426,698.00	$213,349.00	$128,009.40	$85,339.60
2000	$496,381.00	$248,190.50	$148,914.30	$99,276.20
2001	$717,658.00	$358,829.00	$215,297.40	$143,531.60
2002	$477,958.00	$238,979.00	$143,387.40	$95,591.60
2003	$82,295.00	$41,147.50	$24,688.50	$16,459.00
2004	$678,165.00	$339,082.50	$203,449.50	$135,633.00
2005	$969,980.00	$484,990.00	$290,994.00	$193,996.00
2006	$1,855,394.00	$927,697.00	$556,618.20	$371,078.80
2007	$1,839,083.00	$919,541.50	$551,724.90	$367,816.60
2008	$2,698,467.00	$1,349,233.50	$809,540.10	$539,693.40
2009	$3,137,486.99	$1,568,743.49	$941,246.10	$627,497.40
2010	$1,073,362.00	$536,681.00	$322,008.60	$214,672.40
Thru August 2011	$1,878,965.00			

III. Geothermal Working Group Evaluations

The Geothermal Working Group advises a course of action that leads to energy independence and away from the dependence upon imported fuels. The Working Group advocates developing and producing a clean, renewable, and local energy portfolio that includes geothermal. Hawaiian Electric (HECO) vice president, Robbie Alm, wrote "Our state is 90 percent dependent on imported fossil fuels for all our energy needs. This is no longer sustainable. It threatens our energy and economic security and our environment.[1]"

There are no fossil fuel reserves in Hawaii. However, Hawaii does have natural and renewable energy resources. Using them can provide the means to lessen the impacts of an energy crisis.

Recently, HELCO performed high-level transmission studies to evaluate the expansion of geothermal generation. These studies provide a general appraisal of the transmission requirements for additional geothermal generation, but are not equivalent to the detailed interconnection studies required for specific projects.

[1] From PUC testimony, September 2011, see PUC.Hawaii.gov/dockets.

IV. Recommended Steps for Hawaii State Legislators

- Make the allocation of geothermal royalties more transparent to show how benefits come back to the community. Designate the records of the allocations to be public domain.

- Establish a community advisory board to offer suggestions to the DLNR about how royalties generated by geothermal power plants are spent. The advisory board should be members of the communities that host existing or future geothermal power plants and/or those who are most impacted by the development of geothermal energy.

- Encourage the DLNR to use geothermal royalties to identify promising geothermal sites and to further develop the resource.

- In light of the probability that oil will reach $200 per barrel (Lloyds of London), the legislature is requested to commission a study to show the economic impact of various prices of oil.

- Facilitate development of geothermal with a critical review of the geothermal permitting process, regulatory capabilities, and possible investment incentives.

Environmental Impacts

SCR 99 was mindful that geothermal energy development impacts adversely both the natural and cultural environment. It stated:

WHEREAS, previous geothermal development has raised sensitive issues regarding the impacts on native Hawaiian cultural and spiritual practices;

WHEREAS, Hawaii needs a sustainable energy market that strikes a balance between economic, community, and environmental priorities;

BE IT FURTHER RESOLVED that the working group consider the potential impacts of expanding geothermal energy production on native habitats, pristine forest environments, and native Hawaiian values and practices, and recommend mitigative measures to ameliorate any adverse impacts that may be caused by geothermal energy production expansion;

Potential adverse impacts are listed below:

- Interference with worship of the Goddess Pele
- Interference with certain Native Hawaiian practices
- Rainforest destruction
- Possible health and safety impacts
- Disruption of the way of life for nearby residents
- Hydrogen sulfide and other air quality issues
- Noise
- Increased strain on an inadequate infrastructure
- Impact on native fauna and flora

Hawaii laws say the exploration and development of geothermal resources can be permitted within conservation, agricultural, rural, and urban areas. That is because the vast majority of resources are located under volcanic rift zones and usually do not impact human activity on the surface. Because of volcanic hazards, geothermal potential is associated with predominantly rural areas most of the time and undeveloped lands where direct human impacts or occupation are minimal, such as the Wao Kele O Puna rainforest.

Industrialization of these rural or wilderness areas and the implementation of an industrial activity–the generation of geothermal power–is of major concern for those living adjacent to it or who value the biological diversity preserved in those areas.

1. The larger the quantity of geothermal energy developed, the larger the impacts to adjacent residents and the environment. Proponents of greatly expanded geothermal energy expound scenarios where major displacement of existing oil-fired electrical generation is achieved, with new high-energy input industries introduced on island to facilitate the transition. There has been no

analysis done by this Working Group on the environmental or social impacts of any large scale development scenarios.

2. It is apparent that under current assumptions, HELCO will not absorb more than another 10 to 20 MW of baseload geothermal energy in the near future (i.e. 2015). As stated, proponents of greatly expanded geothermal energy envision scenarios where total displacement of all oil-fired electrical generation (100 - 200MW or more of geothermal generated electricity) is practical, with a new high-energy input industry to absorb that energy until the electrical grid can be totally converted from oil-based fuels.

3. Prior to any expansion of geothermal facilities, members of this Working Group have asked that reviews of the air quality/hydrogen sulfide emissions rules, noise regulations relating to geothermal exploration, drilling operations, and production operations should be undertaken. Those are the environmental impacts that caused great alarm and objection in years past.

4. DLNR participation in future Working Groups is essential. They are a major influence in Hawaii's land use and management. They are tasked with geothermal subzone designation. That kind of review would be most beneficial in the education of potential "neighbors" on the slopes of Hualalai and/or the Kawaihae region.

5. Future review committees should seek input from DOH's regulatory divisions as well. They are ostensibly responsible for responding to neighbor complaints and overseeing air emissions and other pollutants. What is their current ability to handle and regulate and respond to emergency situations? What is their role during an emergency, either in Lower Puna or at a new geothermal site on the slopes of Hualalai and/or Kawaihae?

6. The Hawaii County Civil Defense and other County agencies play a role in the development of geothermal energy and mitigating its adverse environmental and social impacts. This Working Group did not interact with these County agencies. We encourage future Working Groups to do so.

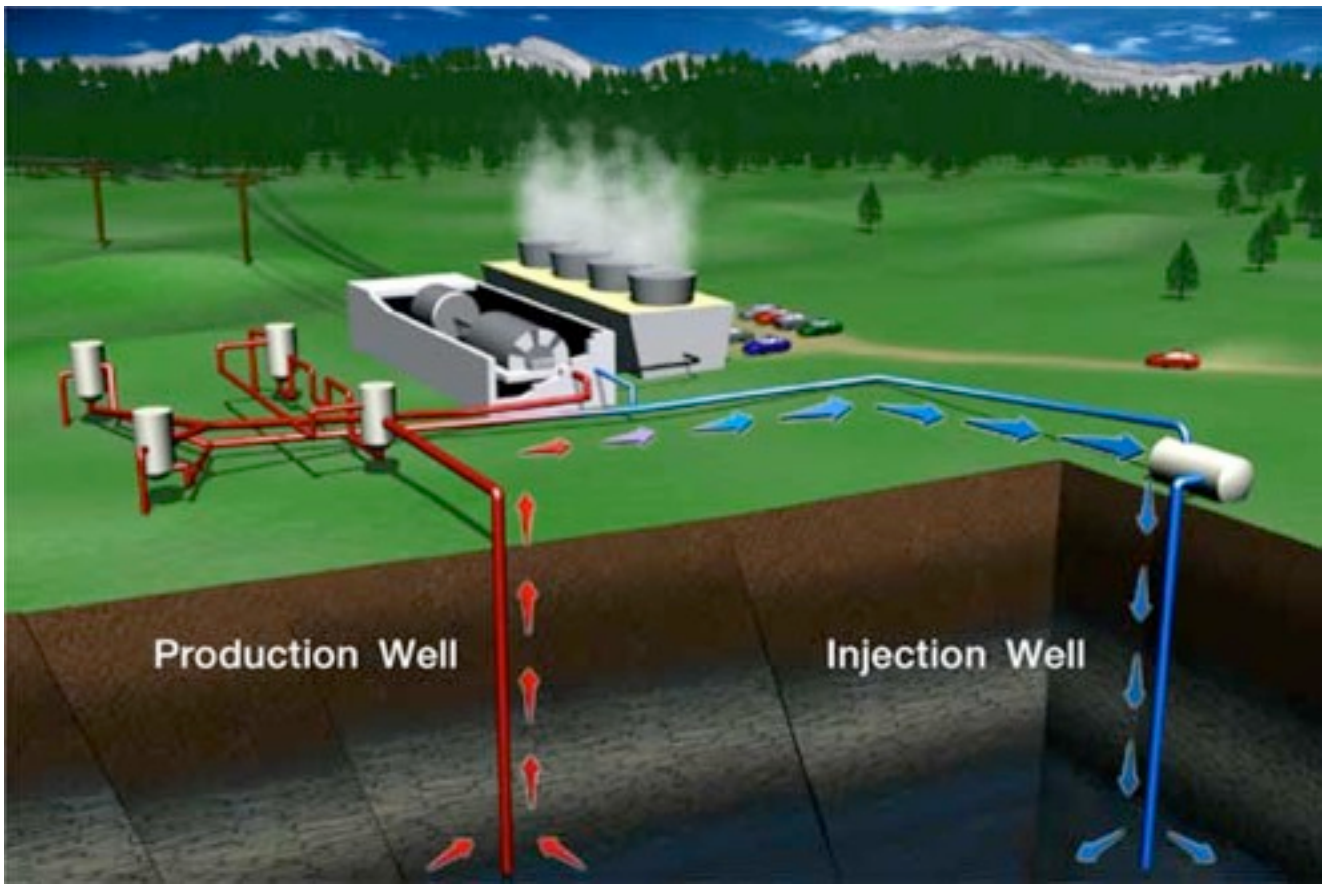
Since the environmental impacts are site specific, there can be no information on the impact without identifying the location of the resource or how it will be developed. The most critical issue is to identify the resources available. More testing is needed. The downside of the data available on Big Island's geothermal resources is that it is old and obtained using techniques that have been much improved in recent decades.

Resource Analysis and Impact Assessment

There are two projects the Working Group recommends be funded: first, testing and identifying specific locations that hold promise to be geothermal generation sites and, second, analyzing the impact of transition to geothermal upon the existing infrastructure. For example, shippers and dock workers may lose work importing supplies for petroleum-based plants. Funding for a study is needed and the Working Group recommends the legislation make it available.

A concern of neighbors to the geothermal plant in Puna is the need to plan for a possible malfunction in the plant's operation that might lead to a release of toxic gas. An Emergency Response Plan has been prepared and is updated from time-to-time. Copies of the ERP are distributed to all the responding agencies and available at the Pahoa Public Library. The working group recommends that the ERP be made available on-line for community review and information.

Some members of the Puna community insist that any expansion of PGV's capacity be done under the strictures of a contested case hearing. The Working Group is of the opinion that a robust environmental impact statement can mitigate community concerns. The contested case hearing is not recommended at this time.



Infrastructure and Engineering Considerations

Background Information

The electric transmission system on the Island of Hawaii is owned and operated by Hawaii Electric Light Company (HELCO), an investor-owned utility regulated by the Hawaii Public Utilities Commission. Hawaii Island has a land area of approximately 4,000 square miles with approximately 80,000 electric utility customers. The transmission system is primarily comprised of transmission lines built and operated at 69,000 volts. Currently, there are approximately 650 miles of transmission lines with 22 transmission substations on the Hawaii Island electrical grid.

HELCO's transmission system interconnects HELCO's major generation sites at Keahole (80.8 MegaWatts), Kanoelehua (55.2 MW), Puna (34.5 MW), Shipman (13.5 MW), and Waimea (7.5 MW), with major independent-power-producers at Hamakua Energy Partners L.P. (HEP - 60 MW), and Puna Geothermal Venture (PGV - 30.0 MW). Other *as-available* generation sites are also interconnected to HELCO's transmission system: Puueo Hydro (3.25 MW), Wailuku River Hydro (12.1 MW), Tawhiri Power LLC (Pakini Nui) Windfarm (21.0 MW), and Hawi Renewable Development, Inc. (10.56 MW). In addition, four dispersed-diesel units (1 MW each) are interconnected to the distribution system at the Panaewa substation, Kapua substation, Ouli substation, and Punaluu substation.

The majority of the firm-capacity power plants on HELCO's system are located on the eastern half of the island, while approximately half of the customer loads are on the western half of the island. HELCO firm-capacity power plants at Kanoelehua, Puna, and Shipman, and firm-capacity independent-power-producer plants at PGV and HEP are located on the eastern half of the island. HELCO firm-capacity power plants at Keahole and Waimea are located on the western half of the island. Net power generally flows from the power plants in the East to the load centers near Kailua-Kona on the westside.

There are four basic transmission routes for this cross-island power flow. Two transmission routes follow the path of Saddle Road between Mauna Kea and Mauna Loa, then through the South Kohala area on to Kailua-Kona. A third transmission route traverses from Hilo, through the northeast part of the island along the Hamakua Coast, through Waimea Town and then through the South Kohala area on to Kailua-Kona. The fourth route traverses from Hilo, through the Volcano area, through the South Point area, continuing through South Kona on to Kailua-Kona.

The HELCO transmission network allows for redundancy in the event of an outage to a line or system component. HELCO uses single-contingency criteria for the planning of its transmission system, meaning the system is designed to maintain normal voltages and line loading in the event a

single transmission line goes out-of-service. However, HELCO's transmission system is not designed to maintain normal voltages and line loadings should simultaneous outages occur in two or more transmission lines. Because such multi-line outages can result in large and serious system disturbances, proper operation and maintenance of HELCO's transmission system is vital to providing reliable service.

Transmission System Upgrade Study

A high level review of the transmission system upgrades required to interconnect additional geothermal power plants on Hawaii Island was done by Hawaii Electric Light Company. Two geothermal expansion scenarios were reviewed: one evaluated the addition of 50 MWs of geothermal energy from the East Rift zone and the second evaluated the addition of 50 MWs of geothermal energy on Hualalai on the West Side of Hawaii Island.

The evaluation concluded that for a 50 MW expansion on the East Rift zone, an additional transmission line from the new facility to Hilo, and an additional cross-island transmission line from the East side of the island to the West side would be required. For a 50 MW expansion near Hualalai, transmission lines from the new facility to existing transmission facilities on the West side of the island would be required but another cross-island transmission line would not be required.

HELCO's high-level transmission studies provide a general evaluation of transmission requirements for additional geothermal generation, but are not equivalent to the detailed interconnection study required for a specific project. More detailed interconnection studies would be performed at the time a geothermal-development project was identified and more specific size and location information was available. Cost estimates for interconnections would be developed at that time.

Note Regarding the Next Section of the Report

Many of the issues discussed in the next section, The Cost of Energy, will be evaluated in detail as part of HELCO's next Integrated Resource Planning process directed by the Hawaii Public Utility Commission.

The Cost of Energy

Geothermal generation on the Big Island

Geothermal energy has been an important source of electricity on the Big Island since the 30-megawatt (MW) Puna Geothermal Venture (PGV) plant began operation in 1993. PGV has been providing baseload power, generally between 25 and 30 MW—approximately 20% of the electricity delivered by HELCO.

Big Island residents have the highest use of their electricity in the evening, roughly between 6:00 and 9:00 p.m., when families are home at dinnertime. The peak demand on the Big Island is approximately 185 MW. During peak hours, as well as during the day when HELCO customers demand about 160 MW, HELCO usually purchases as much geothermal electricity as is available. Between midnight and dawn, however, electricity consumption is at its lowest, dropping to about 90 MW. During these hours, many Big Island power plants reduce their output, as there is no need for the electricity. The geothermal power plant is curtailed during these off-peak hours by several megawatts.

Geothermal power plants worldwide generally operate as baseload facilities; that is, producing a steady output 24 hours daily, seven days a week. Some facilities, such as PGV, do reduce output to "follow the load" during off-peak hours. However, geothermal wells are not turned on and off as power requirements change; steam is still produced, but if not used to generate electricity it bypasses the turbines and is simply injected back into the earth. Thus, there is some unused heat during the off-peak hours.

PGV's contract to provide electricity to HELCO was negotiated at a time when renewable electricity was tied to the price of oil. The current contract runs at least to December 31, 2027. It is not expected that future contracts for renewable electricity, including any for geothermal, would be tied to oil prices.

Potential benefits of increased geothermal power

Geothermal energy has a number of potential benefits for Big Island residents. Because it does not require imports of fossil fuel, it can contribute to more predictable and stable utility rates. This will be particularly important as oil becomes less available and more expensive.
The environmental impacts of producing, transporting, refining and using oil will also be reduced. The negative impacts of drilling for and shipping oil are currently "exported" to other countries, often affecting communities with environmental standards weaker than those of the US. Within Hawaii, we could expect to minimize oil spills and greenhouse gas emissions relating to burning fossil fuel.

Geothermal is a resource which is sustainable for centuries, given Hawaii County's geology. The heat resource is essentially inexhaustible. While individual wells or geothermal fields may change

over time, including changes in the proportion of liquid to vapor in the geothermal fluid, the presence of magma due to the "hot spot" beneath Hawaii ensures that heat will continue to be present in certain locations.

Also, although it is beyond the scope of the resolution, geothermal energy can provide more than just electricity. During off-peak hours, when Hawaii Island residents do not use as much electricity, geothermal heat could be used for a variety of other purposes, such as making liquid fuels, charging batteries, or supporting agricultural enterprises which require heat. These enterprises could contribute to Hawaii's clean energy future, and can also create jobs in addition to those needed to drill geothermal wells and operate the power plant.

State statute provides for the distribution of royalties paid by geothermal developers for the electricity they sell. Presently, 50% of the royalties are retained by the State of Hawaii Department of Land and Natural Resources, while 30% go to the County of Hawaii and 20% to the Office of Hawaiian Affairs. Additional electricity generation could provide more income to these agencies.

Pending additions to capacity

PGV and HELCO negotiated a contract for an additional 8 MW of capacity. If approved by the Public Utilities Commission, the contract would be highly unusual for a geothermal developer: it would allow for fully-dispatchable power. This means that HELCO operators would be able to control how much geothermal electricity is accepted on the grid, essentially allowing PGV's output to follow instantaneous changes in the load as well as providing peaking power. Additionally, the facility would add inertia to HELCO's system, which would help with grid stability. As is current practice, if steam from the geothermal wells is not needed for electricity, it will be injected into the reservoir. These additional 8 MW can be generated without additional production or injection wells being drilled.

In addition, PGV has obtained County and State permits to double its capacity to 60 MW, which would involve drilling additional wells. Though there is presently no demand for this amount of additional power on the Big Island, successful demonstration of fully dispatchable geothermal power could lead to more opportunities for expanded use of geothermal energy to meet existing demand.

The Big Island's geothermal resource

A number of assessments of the geothermal resource throughout the Hawaiian Islands have been conducted over the decades, with the most recent state-supported report produced in 2005. This report, "Assessment of Energy Reserves and Costs of Geothermal Resources in Hawaii," calculated the geothermal reserves for the state. Note that "reserves" is different from the total resource—estimates of reserves reflect the amount of recoverable heat energy anticipated to be present at drillable depths, while the total resource includes all underground heat and is a larger number.

Reserves were calculated for Big Island resource areas, including the Kilauea East Rift Zone (KERZ) as well as other rift zones. The combined minimum capacity for the Big Island is estimated to be 488 MW, but 1,396 MW is considered the most likely amount of reserves.

The calculation of reserves involves assumptions about the amount of heat which can be expected to be recovered at the surface and the efficiency of converting that heat to electricity. The calculation takes into account the reservoir area, its thickness, its average temperature, its average rock porosity, and other factors. It does not, however, imply that this energy can be exploited commercially.

It is highly likely that the commercially developable geothermal resource is smaller than the reserves. There is significant uncertainty regarding reservoir characteristics. In some areas, conditions may not support geothermal development; for instance, there may be heat but not sufficient fluid to transport the heat to the surface. In other areas, such as national parks, geothermal power plants cannot be developed.

The following table lists the estimated reserves for various Big Island rift zones, according to the 2005 assessment mentioned above. The smaller number is the calculated minimum capacity of the rift zone, with the larger number being the most likely capacity, reflecting the arithmetic mean. It should be noted that actual exploratory measures should be employed to confirm or modify these calculations. An updated assessment, including additional exploration, could provide more accurate numbers.

Puna Geothermal Venture has stated that they believe their leasehold in the lower KERZ is capable of producing 200 MW, which is consistent with the estimates given below.

Table 1.1 Estimated Geothermal Reserves, Island of Hawaii[1]

Rift Zone	Minimum capacity (MW)	Mean Capacity (MW)
Lower KERZ	181	438
Upper KERZ	110	339
Lower Kilauea SW Rift	64	193
Upper Kilauea SW Rift	68	201
Mauna Loa SW Rift	35	126
Mauna Loa NE Rift	22	75
Hualalai	7	25
TOTAL (rounded)	488	1396

[1] GeothermEx, Inc., 2005; *Assessment of Energy Reserves and Costs of Geothermal Resources in Hawaii.* Prepared for the State of Hawaii DBEDT.

The cost of geothermal electricity

Geothermal is a fully commercial renewable energy technology implemented in many countries around the world. The actual cost of geothermal electricity is currently significantly less than oil-generated electricity in Hawaii, in part due to the rising price of oil. For a 30-MW geothermal power plant in Hawaii designed to generate baseload power, the cost per kilowatt-hour is less than $0.10.

However, future costs will not necessarily be the same. For instance, should the additional 8 MW of load-following capacity come on line, the cost of generating a kilowatt-hour of electricity may be higher due to the ancillary services being provided.

The 2005 assessment provided an estimate of the levelized cost of power from a new 30-MW baseload geothermal power plant. The report made the following assumptions:

- Capital costs in the range of $2500-$5000/installed kW
- O&M costs in the range of $0.04-$0.06/kWh
- Initial drilling costs per well of $4 million to $9 million

With these assumptions, the mean levelized cost of power was calculated to be approximately $0.08 per kilowatt-hour.

Issues relating to expanding geothermal's baseload contribution

- PGV currently holds permits to double its output

Puna Geothermal Venture could double the capacity of its current power plant to 60 MW. However, currently there is no market for this amount of electricity on the Big Island.
Public hearings for the County of Hawaii's geothermal resource permit were completed years ago. At least some State of Hawaii permits are also in hand.

- How many, if any, additional permits are required?
- How many new production and injection wells will be needed?
- How many years would it take to develop another 30 MW of capacity?

- Other power plants currently provide baseload power

An existing independent power producer, Hamakua Energy Partners (HEP), has a 60 MW naphtha plant with a contract which runs from 2000 to 2030. HEP currently provides both capacity and electricity. It generates baseload power for HELCO, including during off-peak hours. Some HEP output is expected to be displaced by PGV's anticipated 8-MW addition as well as by the expected Hu Honua biomass-fired power plant in Pepeekeo, according to Jay Ignacio of HELCO (personal communication, Oct. 11, 2010.)

- Could additional geothermal capacity displace more generation from HEP?
- If so, what are the implications for the current contract with HEP?

- Existing fossil-fired utility power plants

Presently, HELCO distributes power from approximately 180 MW of generating capacity, including diesel and residual fuel oil plants around the island.

  - Which of these are scheduled for retirement?
  - How many years of economic life remain for each plant?
  - What is the financial impact of stranded investment on ratepayers and utility stockholders if any of the plants were decommissioned?
  - Could a new geothermal plant provide the stability and inertia presently provided by HELCO's fossil-fuel steam plants?

Challenges to increasing the proportion of electricity generated from geothermal energy

- "All eggs in one basket." There is strength and security in a diversified portfolio.
- Transmission issues. Presently, most of the electricity on the Big Island is generated on the east side, whereas the load is increasing on the west side. Electricity is lost during transmission, and transmission lines are subject to disruption.
- Mismatched demand. Demand (electricity use) is not well matched to geothermal's most cost-effective and technically mature application: 24/7 baseload production. Demand fluctuates throughout the day, whereas geothermal power plants are best suited to providing a steady output around the clock.
- Lack of market. Presently, HELCO does not need additional baseload power. HELCO does not anticipate needing more large power plants in the immediate future. If additional geothermal capacity were to be developed soon, it would require either displacing existing plants which have contracts for baseload electricity, or developing new markets—perhaps for non-electric uses of geothermal heat.

Possible actions to address these challenges

- Ensure that HELCO's portfolio remains diversified, ideally with a variety of renewable resources making significant contributions to the grid.
- Develop geothermal resources on the west side of the island to minimize transmission challenges and to generate electricity closer to where it will be used.
- Modify electrical demand to create markets for geothermal electricity during off-peak hours. This could include storing the energy in various forms, such as charging batteries, producing fuels such as hydrogen or ammonia, charging electric vehicles, or making ice for cooling applications during peak hours.
- Develop non-electric uses for off-peak geothermal energy, such as agricultural applications requiring heat—food or lumber drying, growing media pasteurization, biofuels production, and heating greenhouses. The County of Hawaii completed a feasibility study in 2007 which examined some of these applications[2].
- Explore the costs of contract buy-out and decommissioning existing power plants.

[2] Okahara & Associates, Inc., 2007. *Feasibility Study: Geothermal Direct Use, Kapoho/Pohoiki Area.* Prepared for the County of Hawaii Department of Research and Development.

Community Benefits

The PGV royalty is calculated according to the value of the resource using a formula developed by DNLR and the US Department of Interior; from that figure, 10 percent of the resource value is designated royalty. With regard to the royalties calculation and distribution, the Working Group recommends that Hawaii legislators revisit the way money is disbursed to the community. Moving forward, any expansion of geothermal would need to include a better package for fair compensation to the trust corpus of the ceded lands. The Hawaii State constitution clearly states "...proceeds and income derived on ceded lands (5f)..." are to be used to improve the conditions of the native Hawaiians as defined by the ACT. Hopefully, the mechanism can be developed by the legislature in concert with the local communities. Public hearings should be held to address all proposals being offered by all concerned.

The US Department of Energy is currently funding the development of several modifications to public transportation that will permit the transition from fossil fuels to hydrogen fuel for the Volcanoes National Park buses and the Hele-On trans-island bus service. Fuel-cell cars are being tested by the armed forces on Oahu and Big Island and will eventually support the establishment of refueling stations island-wide. The technology is available, but decades of subsidies, legislation favorable to the petroleum industry, and life-style choices by consumers has kept fossil fuel artificially profitable and has stymied the deployment of alternatives to gasoline-powered cars and buses. Transitioning to fuels that can be produced on Big Island and creating the attendant infrastructure of fueling stations and repair shops is strongly recommended.

Not only can geothermal power plants produce fuel for alternative-fuel power plants and vehicles, but also agricultural fertilizer that can replace products that are presently imported and expensive to farmers. Thus, the sale of fuel and fertilizer has the potential to become a major export business. Exporting hydrogen fuel in the form of ammonia from geothermal plants on Big Island to Oahu is one method of sharing the power resources with the population centers.

Insofar as as the usage of royalties from geothermal for community benefits has been masked by commingling the funds with other revenue streams provided to the Hawaii Department of Land and Natural Resources, the DLNR is requested to seek approval to direct monies received from geothermal funds to be used to explore and to identify promising geothermal sites and to further develop the resource. The change will permit an openness in accountability and allow the public to discern a prominent and unmistakable community benefit.

Additionally, a community advisory board should be established to offer suggestions to the DLNR about how royalties generated by geothermal power plants are spent in the future, especially after all the potential geothermal resource sites have been identified and tested.

Royalties Disbursement

Detailed Accounting of Geothermal Royalties

Geothermal royalties are based on power production and the sale of electricity to Hawaii Electric Light Company (HELCO). The geothermal royalties are paid directly to the Department of Land and Natural Resources (DLNR) by Puna Geothermal Venture (PGV) and DLNR allocates the royalties in three ways:

1. Department of Land and Natural Resources receives 50%
2. County of Hawaii receives 30%
3. Office of Hawaiian Affairs (OHA) receives 20%

DLNR submits an annual report to Hawaii legislators concerning geothermal royalties and the status of the inter-island power cable development. The figures below are taken from these reports. The amount of geothermal royalties paid to the State of Hawaii fluctuates each fiscal year, since power output and sales to HELCO vary.

Specific Distribution and Use of Royalties

The Department of Land and Natural Resources is responsible to effectively manage and develop geothermal resources, to protect the health and safety of the public, and to ensure the continued viability of the resource for the future. At present, the County of Hawaii benefits exclusively from geothermal power generation, which provides 20% of the electricity demanded island-wide.

The geothermal royalties are included as part of the $15.1 million transferred to the Office of Hawaiian Affairs each fiscal year. Based on its budget process, OHA allocates the $15.1 million, but not specific revenue sources, such as geothermal royalties.

OHA's budget is allocated based on approved work plans developed by staff. These work plans are derived from OHA's Strategic Plan, Strategic Priorities, and Strategic Results. The Strategic Plan for 2010-2016 focuses on the six Strategic Priorities:

1. Kahua Waiwai - Economic Self-Sufficiency
2. Aina - Land and Water
3. Moomeheu - Culture
4. Mauli Ola - Health
5. Ea - Governance
6. Hoonaauao - Education

The Board of Trustees (BOT) approves OHA's budget. The BOT has exclusive authority to decide how the "ceded lands revenue" is used to better the conditions of Hawaiians. Article XII, section 6 of the Hawaii State Constitution gives the Board the power to administer and manage "...all income and proceeds from that *pro rata* portion of the [SS 5(f)] trust referred to in section 4 of this article for native Hawaiians..." The Legislature's role is limited to quantifying Hawaiians' interest in the income and proceeds from the lands in SS 5(f) of the Admissions Act (refer to the Attorney General Opinion 03-04 regarding the Transfer of Ceded Land Receipts to OHA without Legislative Appropriation).

On June 27, 2006, OHA entered into an Agreement of Sale with The Trust for Public Lands (TPL) to purchase Wao Kele O Puna. The parties wish to preserve the property's natural and cultural resources and maintain traditional and customary practices through appropriate resource management. Funding in the amount of approximately $3.4 million was provided by the USDA Forest Service Forest Legacy Program and the balance was paid by OHA. No DLNR funds were used for the purchase.

Land Trust is a nonprofit organization as described in 501(c) of the Internal Revenue Code of 1986, that protects land by working with landowners who wish to donate or sell fee title or conservation easements to maintain conservation values associated with the land.

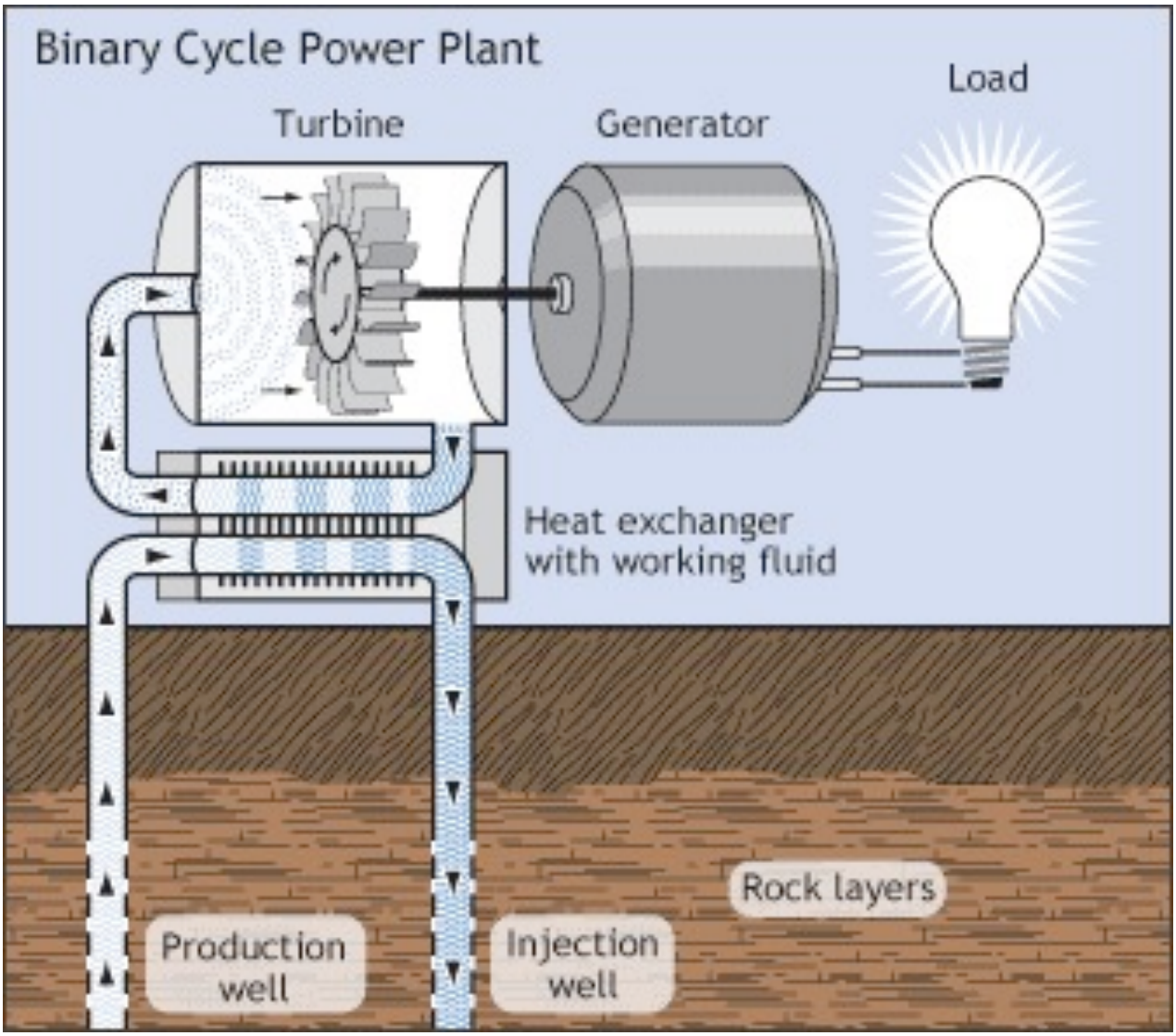
Use of the property complies with the Findings of Fact and Conclusions of Law and Final Declaratory Judgment/Injunction issued on August 26, 2002 in *Pele Defense Fund versus The Estate of James Campbell, Deceased, et. al*, Civil No. 89-089. The judgment opined that the owners of the land are not barred from and may seek to develop the undeveloped portions of the land consistent with applicable law. The developed areas as of January 1, 2001, are the access road, geothermal drill sites and areas cleared for geothermal drill sites. An advisory council consisting of the Pele Defense Fund and other interested community members, mutually selected by DLNR and OHA, developed a management plan.

The management plan included an inventory and assessment of natural and cultural resources, historical sites, risks, threats to resources, interpretive values, and economic development potential. The economic development-potential section identified uses consistent with the property's status as a forest reserve, the protection of traditional and customary uses of the site, sustainable use and protection of the resources of the site, and the terms of the Forest Legacy Program funding. The parties agreed to protect and enhance native plant and wildlife habitat, the natural, scenic and open-space nature of the property. The parties worked to plug an existing, but abandoned, geothermal well shaft on the property.

V. Geothermal Development in Hawaii

Geothermal can be a key component in a diversified energy portfolio for Hawaii County. Unlike solar and wind power, it is a "firm" resource—always there. Volcanic molten rock (magma) remains below Earth's crust, heating nearby rock, rainwater, and seawater that has seeped into the earth. Some of this hot water travels back up through faults and cracks and reaches Earth's surface as hot springs or geysers. Most of it stays deep underground, trapped in cracks and porous rock. This natural collection of hot water is called a geothermal reservoir.

Geothermal production wells bring the hot water to the surface and use its heat to vaporize a working fluid through a heat exchanger. The powerful expansion of the fluid from liquid to gas drives turbines that spin generators to produce electricity. Afterward, the hot water and gases are re-injected back into the injection zone below the water table. The working fluid is condensed and used again. This is a binary-cycle plant. The closed-loop circulation system means that no excess gases or fluids reach the open air.



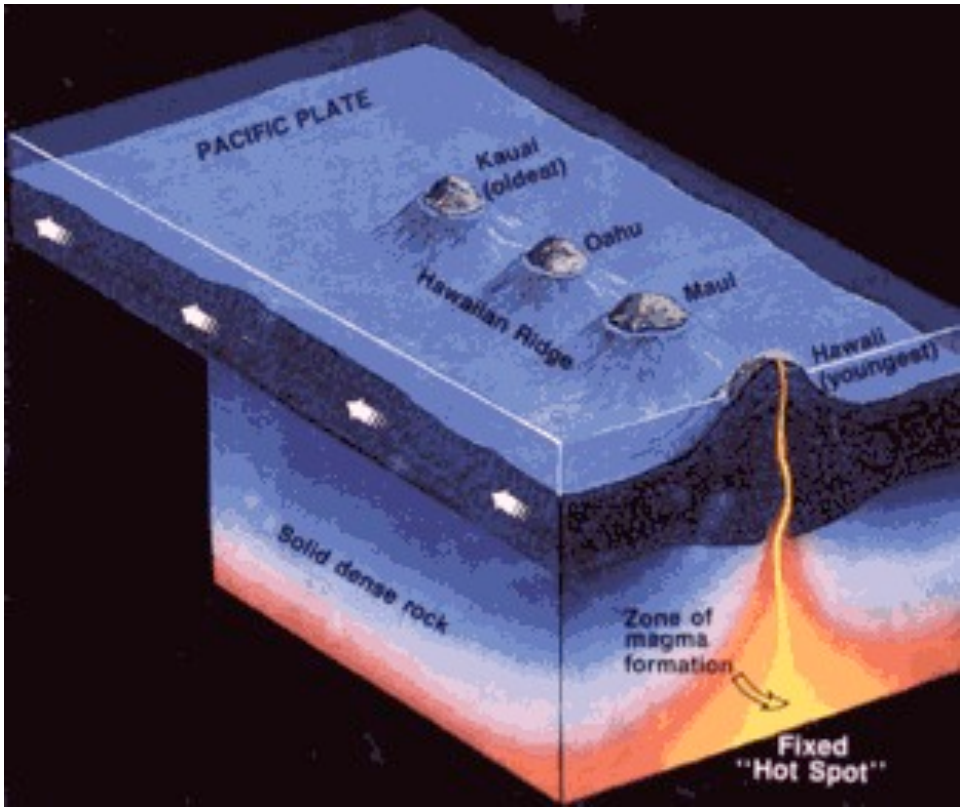
In 1993, the Puna Geothermal Venture Facility, located 21 miles south of Hilo on the Big Island, became the first commercial geothermal power plant in the state of Hawaii. Its binary-cycle plant produces about 30 megawatts of power, or 20 percent of the island's needs. That's enough electricity for 30,000 homes. PGV saves HELCO the equivalent of 144,000 barrels of petroleum a year. PGV is capable of expanding capacity and producing more power. Despite being restricted to the Big Island of Hawaii, geothermal produces thirty-one percent of Hawaii's renewable energy resources statewide.

The state has mandated that 20 percent of the electricity generated by public utilities comes from renewable sources by 2020. Yet, despite its efficiency, stability, and long-term viability, geothermal energy is not always the first consideration in the discussions of expanding energy resources. The public needs a greater awareness of geothermal energy to understand its potential.

Geothermal resources

Hawaii County lies above a geological *hot spot* in the earth's mantle that has been volcanically active for the past 70 million years. Big Island has had the most recent activity. Because of this, Hawaii County has immense potential for geothermal energy, both for electrical generation and fuel production. Geothermal power potential on the Big Island is estimated at between 500 and 700 Megawatts.

Geothermal interest has been motivated by the fact that imported oil is used to supply over 90 percent of Hawaii's energy needs; no other state in the U.S. is so critically dependent on imported oil. Geothermal is regarded as a renewable source and can help to make the island less dependent on imported energy.



VI. References to Subject-Matter Experts

Iceland report http://english.aljazeera.net/video/europe/2011/04/201142216515860992.html

While the vast majority of investment in the energy transition will come from the private sector, government has an important role in creating policies and incentives that encourage investment conditions.

Globally, geothermal exploration and drilling has, on average, a 50% or less success rate; it is very difficult to find commercial financing because of this risk. Hawaii has some major advantages, though: Hawaii has identified geothermal resource sites, state agencies are familiar with geothermal, there are local engineers with expertise, there are local educators with expertise, a local workforce is available, and the transmission lines are not far from the most promising resource sites. These factors make Hawaii a desirable location in the eyes of lenders, investors, and the renewable energy industry. Government can tip the balance in Hawaii's favor by offering appropriate incentives.

See ***Appendix O*** Barriers to Geothermal Development

The end of cheap oil is upon us. Given that Hawaii uses oil for 90% of its power, this is an urgent concern. Worse, the price of a barrel today is a false indicator of true reserves and future market costs; current conditions provide an unreliable basis for projections and planning. The uncertainty for businesses and government adversely affects all Hawaii residents.

See ***Appendix J*** Strategic Risks and Opportunities for Business

The use of petroleum in the world is now up to about 30 billion barrels per year. The rate at which we have found new supplies of petroleum over the last 10 years has fallen to an average of only about 10 billion barrels per year. We're obviously in an unsustainable situation. We are now using up a greater number of barrels that we have found in the recent past and that we have reserved in the ground. We are now beginning to use it up relatively quickly--with scary consequences for the future.

See ***Appendix H*** Charles Maxwell interviewed by Wallace Forbes

A looming collapse in credit markets and liquidity could lead to wildly gyrating prices for crude oil within the next five years, with prices falling to $20 per barrel, then possibly rocketing to $500 per barrel, a peak-oil theorist and commentator told the Association for the Study of Peak Oil and Gas conference.

See ***Appendix I*** Association for the Study of Peak Oil & Gas Conference

The depletion of fossil fuels has been occurring since the first ton of coal or barrel of oil was mined. Since these fuels need about 100 million years to regenerate, depletion and technology are in a race. Furthermore, there is considerable evidence that we are mostly just pumping out old fields rather than replacing extracted oil with newly found oil. If current trends continue linearly, then in about two to three decades it will take one barrel of petroleum to find and produce one barrel of petroleum. Oil will cease to be a net source of energy.

The implications of this are obvious, huge, and make an argument for seeking substitutes earlier rather than later.

See ***Appendix G*** Energy Return On Investment by Dr. Charles A. S. Hall

The world is overwhelmingly dependent upon depleting supplies of fossil fuels. There is consensus among credible resource scientists and many economists that petroleum prices will rise to unprecedented levels in a few years. The cost? Volatile oil prices lead to the world-wide market collapse of 2008.

See ***Appendix J*** Strategic Risks and Opportunities for Business

One important goal of the Geothermal Working Group is to assess the minimum return-on-investment that must be attained from Hawaii's energy resources in order to support optimum social and economic activities. Hawaii suffers from an unfavorable return-on-investment for fossil fuel; the cost to drill, refine and deliver petroleum is three times greater than petroleum's benefit for use in utilities, farming, transportation, etc. The conclusion: using fossil fuel to power Hawaii is not sustainable.

See ***Appendix G*** Energy Return On Investment by Dr. Charles A. S. Hall

Government regulations can encourage investments in new energy

Source: http://oilprice.com/Alternative-Energy/Renewable-Energy/The-Need-for-a-Real-Domestic-Alternative-Energy-Policy-in-the-USA.html

Alternative energy (or renewable energy) is a new manufacturing industry paradigm that is in its infancy. However, the discussion is not new, and it looks as if the United States has positioned itself to be *behind history*.

After the oil shortages in the 70's, government officials began discussing energy policy as a matter of national security, but this misses the point of a globally competitive economic world. What is needed now (and what will aid in rebuilding the economy), is a change in paradigm so that America will remain competitive in a rapidly changing economic climate.

In order for new industries to start up, protections against losses have to be guaranteed by the government so industry will take the risk of investing. Governments have the ability to hold and maintain debt even above yearly revenue in order to stimulate economic activity. The government has a duty to utilize tax revenue in order to secure American economic competitiveness.

Alternative energy: A boom industry that needs government stimulus

China now leads the world in installation of wind turbines and solar thermal systems. With a $211 billion investment in 2010 for renewable energy, it is on the rise and should not be discounted to have conversations about drilling in the Gulf of Mexico or whether or not the EPA should remain.

The overemphasis on tax cuts as the only way to spurn private business has become a mantra that is corrosive and harming American capabilities to deal properly with the economic crisis and get people back to work. Alternative energy is a boom industry that needs government stimulus in order to cover the initial losses that would be incurred by private industry.

Source: http://oilprice.com/Alternative-Energy/Renewable-Energy/The-Need-for-a-Real-Domestic-Alternative-Energy-Policy-in-the-USA.html

Analysis by Robert Rapier, author and energy consultant

Normally, consumers consider falling oil and gasoline prices to be good news. They have to pay less to fill up their tanks. And if the reason for that is that oil supplies are increasing at a rate faster than demand is increasing, it can indeed be a good situation for consumers, and good for the economy.

But here's the bad news: that is not the case today.

Oil prices fell to below $90 a barrel, their lowest level in six months. I think oil prices are likely to fall further in the short term, and gasoline prices won't be far behind. While this news alone does mean that consumers will get some relief, the broader picture is grim. The reason oil prices fell by so much is not because a lot of new production came online, but rather because the economy is very sick, and a lot of people are out of work. Economic activity continues to be weak, and that means demand for oil is expected to be weak. In short, not as many people can afford oil and the things made from oil.

However, oil is a global commodity, and some economies continue to boom. Therefore, I don't expect prices to go down and stay down. Growth in just China and India will see to that. The Long Recession hypothesis says that when there isn't much spare oil production capacity, growth in developing countries will tend to keep oil prices high. But high oil prices are a drain on economies that are highly dependent upon oil (like the United States). Thus, if oil dependent countries are in recession during a time that oil production capacity isn't growing (or worse, shrinking), they are going to have a pretty tough time coming out of that recession.

Or a simpler way to put it is this. It may be that the U.S. economy and America's per capita oil consumption of 23 barrels of oil per person per year can't grow in the face of $100 oil. But if countries like China and their 2 barrels of oil per person per year continue to grow while buying $100 oil, then we have truly entered a new paradigm. What may happen is that both China and the U.S. end up consuming 5 or 8 barrels per person per year, which could still grow China's economy, while the U.S. gets there by shrinking ours. China's growth is probably the most worrisome factor because we will be competing against them for global oil supplies.

Source: http://www.consumerenergyreport.com/blogs/rsquared/

GE Poll Source: http://www.genewscenter.com

Nearly eight in 10 US consumers — 79 per cent — say in a new survey that they're ready to make short-term changes in their energy use habits to gain longer-term benefits.

Commissioned by GE, the national survey found that 72 per cent believe that, left unchanged, today's energy sources and consumption habits could hurt the country's economic growth. And 63 per cent said they're willing to work with their power companies to help bring about changes in consumption patterns.

According to GE, the survey findings indicate that people in the US are ready to see changes in the nation's energy landscape.

"There are some things that are essential to achieving a desired quality of life, and Americans overwhelmingly agree that investing in our nation's energy future is one of them," said Bob Gilligan, vice president of digital energy for GE Energy Services. "The American electrical grid system has undergone little investment in the past 25 years. Even worse, most generation stations were built in the 1960s or earlier using even older technology. As a nation, Americans recognize that a cleaner, smarter and more efficient energy infrastructure will help create a competitive economic future. The key is to invest correctly — the right way rather than the easy way."

Association for the Study of Peak Oil & Gas Conference
Washington, DC (Platts News Service) - Leslie Moore Mira

"The global rate of production of oil is peaking now," said Tad Patzek, professor and chairman of the department of petroleum engineering at the University of Texas - Austin.

Frank Rusco, an energy director at the US Government Accountability Office, said, "The remaining hydrocarbons will be more costly to get from underground," from a "policy perspective," citing the Middle East as a "fairly unstable" region.

Robert Hirsch, an energy adviser at MISI and former manager of Exxon's synthetic fuels research laboratory, put the state of looming shortages in more dire terms, saying "in the next two to five years oil shortages will get deeper and deeper."

See ***Appendix I*** Association for the Study of Peak Oil & Gas Conference

Lloyd's of London White Paper

1. Energy security and environmental concerns will fundamentally alter the way that we manage and use energy.

2. Modern society has been built on the back of access to relatively cheap, combustible, carbon-based energy sources. That model is outdated.

3. China and emerging Asian economies demonstrated their buying power in the energy markets.

4. Energy markets will continue to be volatile as traditional mechanisms for balancing *supply and price* lose their power.

5. Much of the world's energy infrastructure lies in areas that will be increasingly subject to severe weather.

6. Without an international agreement on climate change mitigation, energy transitions will take place at different rates in different regions.

7. The introduction of *carbon pricing* and *cap and trade* schemes will make the unit costs of energy more expensive. The most cost-effective mitigation strategy is to reduce fossil fuel energy consumption.

8. Businesses must address the impact of energy and carbon constraints holistically, and throughout their supply chains. Tight profit margins on food products, for example, will make some current sources unprofitable as the price of fuel rises and local suppliers become more competitive.

9. The last few years have witnessed unprecedented investment in renewable energy and many countries are planning or piloting 'smart grids'. This revolution presents huge opportunities.

See ***Appendix J*** Strategic Risks and Opportunities for Business

The members of the Geothermal Working Group wish to acknowledge the administrative efforts of Christopher Westlye, who edited and arranged the Geothermal Working Group report.