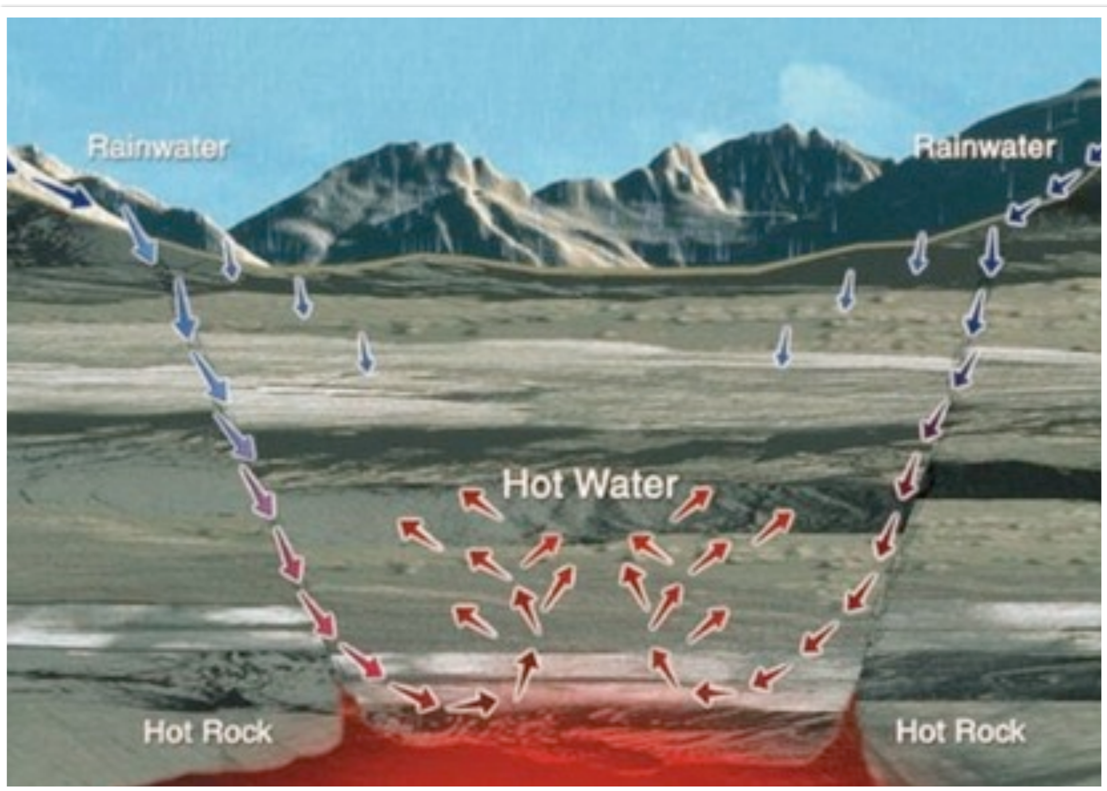
Geothermal Working Group Interim Report

January 2011



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I. Executive Summary

Overview

SCR 99 created the Geothermal Working Group to evaluate geothermal energy as the primary base power for electricity in the County of Hawaii. An analysis of the existing data and a synthesis of expert testimony evince overwhelming support for a plan of action that includes transitioning from fossil-fuel energy plants to local and renewable energy plants, while identifying and responding to public safety and environmental concerns at each stage of development. Funding for important 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 Hawaiians that the transition begin immediately.

The Working Group's principal findings are as follows:

- Multiple geothermal plants are the most prudent approach.

- Historically, geothermal is a lower-cost energy resource.

- Geothermal has the potential to supply baseload electricity, although it has not yet demonstrated baseload consistency in its application in Hawaii.

- Geothermal is a renewable resource indigenous to Big Island and can neutralize the price volatility of petroleum fuel for the county, both in terms of the electrical grid and in terms of transportation.

- Additionally, products that assist island agriculture can be cost-effectively produced with geothermal and replace the importation of products made on the mainland from fossil fuels.

- Thus, Geothermal has a significant potential to be Big Island's primary energy resource.

Purpose of the Interim Report

The ***Geothermal Working Group Interim Report*** is intended for Hawaii state legislators and provides an analysis of developing new geothermal energy resources for the purpose of reducing Hawaii's dependence on foreign petroleum. SCR 99 mandates an 11-member Geothermal Working Group. The resolution instructs the Working Group to consider any potential impacts that expanding geothermal production might have on native forests, wildlife habitat, and Native-Hawaiian values and practices.

Hawaii is the most petroleum-dependent state in the nation; Big Island alone exports $1 billion annually to purchase oil for power. Geothermal is viewed as an important component in a suite of local and available energy resources.

There is an urgency to developing new energy resources because Hawaii, like most of the world, is overwhelmingly dependent upon depleting supplies of fossil fuels. The consensus among credible resource scientists and many economists is that petroleum prices will rise to unprecedented levels in a few years. Since Big Island uses oil for 90% of its power, this is of the utmost concern to leaders in government and business.

In the final analysis, even before factoring in the inefficiencies of transforming fossil fuel to electricity and delivering it to homes and businesses, Hawaii's current method of electrical production is simply not sustainable.

Facts and Forecasts

The International Energy Association (in *World Energy Outlook 2010*) points out that Peak Oil, that is, the greatest amount of oil production that will ever be achieved, is already behind us. http://www.worldenergyoutlook.org/.

Lloyds of London, in it's white paper, *Sustainable Energy Security: Strategic Risks and Opportunities for Business*, warns its business clients to be prepared for $200 per barrel oil by 2013. http://www.chathamhouse.org.uk/files/16720_0610_froggatt_lahn.pdf.

The *Joint Operating Environment 2010*, a United States Joint Forces Command study about the future security environment at the operational level of war, summarizes: “By 2012, surplus oil production capacity could entirely disappear, and as early as 2015, the shortfall in output could reach nearly 10 MBD.” http://www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf.

A world-wide consensus reveals that oil supplies are depleting and that consumers will start to see its effects in a very short time. High prices and volatility in the electricity sector are the two fundamental issues that require immediate action.

The volatility of petroleum-based energy makes business planning very difficult, whereas geothermal energy is stable. Jim Kauahikaua, Chief Scientist at Hawaii Volcano National Park Observatory, says that geothermal energy will be available to Big Island for 500,000 to 1,000,000 years.

Geothermal is the cheapest form of base power for Hawaii. A *Wall Street Journal* article estimated geothermal energy is produced at a cost equivalent to $57 per barrel. As of this writing, January-2011-delivery crude is $88.02 per barrel. Using geothermal as Hawaii's primary source of base power will permit greater manufacturing competition relative to the rest of the world. Our standard of living will also rise relative to the rest of the world. Significantly, using geothermal as Hawaii's primary source of base power will help folks on the lowest rungs of the economic ladder - those who would otherwise have their lights turned off first.

In addition to stability and affordability, geothermal leaves the smallest environmental foot print of the base power sources of electricity. There are no green house gases.

From cheap, “off peak” geothermal electricity, hydrolysis can generate hydrogen and, by taking nitrogen from the air, we can make ammonia. Ammonia is an efficient hydrogen carrier that can be used to power internal combustion engines and as an aid to local agriculture as fertilizer.

Benefits of geothermal energy to the community include sharing in geothermal royalties. Geothermal royalties are based on the value of the resource. The geothermal royalties are paid directly to the Department of Land and Natural Resources 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%

The amount of geothermal royalties paid to the State of Hawaii fluctuates each fiscal year, since power output and sales to HELCO vary. Over the last seven years, however, there is a trend of increasing revenues.

Geothermal Royalties from 2001 to 2009 .... $12,456,486.99

On October 26, 2009, DOE awarded $151 Million in Recovery Act Funding for ARPA-E for research projects. The purpose is for innovative approaches to cut carbon pollution and create jobs. Among others, part of the funds will support energy technologies for geothermal drilling.

On Oct. 29, 2009, the DOE announced that up to $338 million in Recovery Act funding will be granted for the exploration and development of new geographic fields and research into advanced geothermal technologies. (EERE News, October 29)

II. Working Group Evaluation

The Geothermal Working Group advises a course of action that leads to energy independence and away from fossil-fuel dependence. We advocate debate that addresses clean, renewable, and local energy production. We advise transitioning away from the use of imported and polluting fossil fuels. We request that the best and brightest face the challenges of controlling our destiny through innovation rather than depending so heavily upon the importation of foreign petroleum, whose price spikes undermine our economy and, ultimately, our way of life. There are no fossil fuel reserves in Hawaii; there are only 3% in North America. 65% of the world's crude oil reserves are in the Middle East.

After decades of wars and the spread of religious fanaticism in the Middle East, we still depend upon this very unstable and dangerous region to supply the bulk of our energy needs. Demand for oil continues to skyrocket *even* as the supply of oil dwindles. A crisis looms and, unless we act now to avert the inevitable, oil prices will swing wildly in response to political, economic, and military events in foreign countries - events over which we have no control - and that will have catastrophic consequences in our own part of the world.

In the coming months, HELCO will perform high-level transmission studies to evaluate the expansion of geothermal generation. These studies will provide a general appraisal of the transmission requirements for additional geothermal generation, but will not be equivalent to the detailed interconnection studies required for specific projects.

III. Recommended Actions for the Hawaiian Legislature

Fund research and field work to catalog geothermal energy resources available on Big Island.

Fund research and field work to analyze the impact of transitioning from petroleum-fired power plants to geothermal.

Authorize a legislative agenda item to reconsider how the royalties from geothermal production are distributed to the state, county, and the neighborhoods that border geothermal plants.

Designate geothermal funds for programs that benefit local communities and that further develop the resource, rather than placing the royalties in the land fund.

Make a highly-efficient, non-fossil energy future a top priority.

IV. SCR 99 Mandates and Corresponding Interim Report Topics

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: Senator Russell 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

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:
Topic VII. 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:
Topic IX. 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 base-load demand on the Big Island, including an analysis of community, environmental, and economic benefits

See:
Topic VI. The Cost of Energy
Topic VIII. Community Benefits
Topic XI. 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:
Topic VIII. Community Benefits
Topic XI. 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:
Topic XI. 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 Report

V. Overview

Reporting Geothermal Potential

In 2010, Senate Concurrent Resolution 99 was approved by a vote of 23-2 in the Hawaii State Senate and was unanimously approved in the state House of Representatives. SCR 99 created an 11-member Geothermal Working Group to evaluate geothermal energy for electricity in the County of Hawaii. The resolution instructed the Working Group to consider any potential impacts that expanding geothermal production might have on native forests, wildlife habitat, and Native-Hawaiian values and practices. The group is also tasked with recommending steps that can be taken to mitigate any adverse consequences from geothermal.

The ***Geothermal Working Group Interim Report*** is intended for Hawaii State legislators. As a requirement of Senate Concurrent Resolution 99, it provides an analysis for the development of new energy resources to reduce Hawaii's dependence on foreign petroleum.

The Geothermal Working Group advocates discussions on related topics and concerns - primarily, the best integration into the existing electrical-power grid of a variety of renewable energy resources. Hawaii is the most petroleum-dependent state in the nation; Big Island alone exports $1 billion annually to purchase oil for power. The future promises an even greater demand for power. Hawaii can meet tomorrow's power needs by utilizing locally available resources. However, this report is not exclusively concerned with technologies; it also analyzes the community, environmental and economic impacts of energy development in Hawaii.

Geothermal is viewed as an important component in a suite of local and available energy resources. While the Geothermal Working Group does not advocate for one particular vision of Hawaii's energy future, its purpose is stated in SCR 99:

REQUESTING THE ESTABLISHMENT OF A WORKING GROUP TO ANALYZE THE POTENTIAL DEVELOPMENT OF GEOTHERMAL ENERGY AS THE PRIMARY ENERGY SOURCE TO MEET THE BASE-LOAD DEMAND FOR ELECTRICITY ON THE BIG ISLAND.

VI. The Cost of Energy

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? Between 2005 and 2008, volatile oil prices lead to the world-wide market collapse of 2008.

One important goal of the ***Geothermal Working Group Interim Report*** 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. We surmise that for any economic and social system to thrive, it must gain substantially more energy than it uses in obtaining that energy. Thus, 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.

The end of cheap oil is upon us. Given that our island 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 everyone.

Energy comes from many sources – from imported and domestic sources of oil, coal and natural gas, as well as hydropower, and renewable energy – increasingly from wind, solar, and geothermal. Most of these are cheaper per unit energy delivered than oil. There is a critical need for funding to take advantage of resources that exist and that are poised to replace fossil fuel.

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.

At the time of this writing, a barrel of oil on the New York market is $88 (up from $77 last month). Assume that the price of oil increases to $140 a barrel. If that happened, then $2.38 trillion, one fifth of the economy, would be used to buy the oil to run the other four fifths -- *not including* the energy-extraction system itself. Include the energy cost of supporting labor or compensating for environmental destruction and this ratio would increase substantially. In the final analysis, even before factoring in the inefficiencies of transforming fossil fuel to electricity and delivering it to homes and businesses, Hawaii's current method of electrical production is simply not sustainable.

Charles Maxwell, a senior energy analyst

“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.”

“What's happening is that the increase in the world's population and greater use of oil in transportation, particularly in the emerging countries, is working to lift oil demand, and that spurs us to drain a field more quickly, but not necessarily to get a higher proportion of oil out of it.”

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. “The size of accumulation [of oil] is not equated to the rate of production,” he said.

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.”

New reserves from Brazil and production from unconventional sources in the US will not be enough to compensate for depleting reserves, panelists said.

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.

Lloyd's of London White Paper

Independently of what happens in UN negotiating rooms, the US Congress, or multi-national corporate board rooms, Hawaii's legislature and Hawaii's businesses can take action. We can plan our energy needs, we can make every effort to reduce consumption, and we can aim for a mix of different energy sources.

The transformation of the energy environment from carbon to clean energy sources creates an extraordinary challenge for our island. We can expect dramatic changes: prices are likely to rise, with some commentators suggesting oil may soon reach $200 a barrel; regulations on carbon emissions will intensify; and reputations will be won or lost as the public demands that big energy users and suppliers reduce their environmental footprint.

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.

Renewable energy has moved into the mainstream and is now supplying the majority of new electricity in some regions. To increase efficiency and allow the uptake of more renewable energy, radically different infrastructures are being planned around the world. These may include local and trans-national ‘smart grids’ that communicate with household and industrial appliances and electric vehicles, and can send power back into the grid to help regulate demand flows.

There is little sign that energy demand will go down, with forecasts suggesting a 40% increase by 2030. This will require $26 trillion of investment - some 1.4% of global GDP. Given the global commitment to radically reduce emissions and the finite nature of conventional fossil fuel sources, a rapid movement towards a highly-efficient non-fossil energy future would seem to be the logical investment choice.

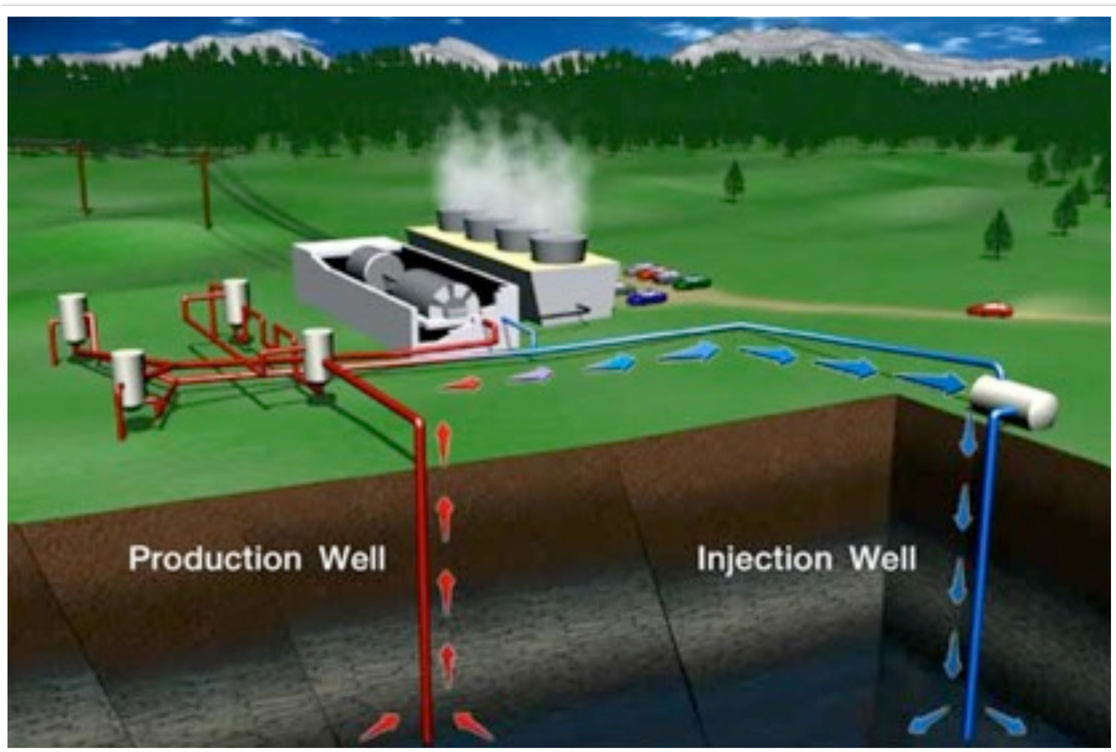
With average rates of decline from current fields, just to maintain current production levels would require the equivalent of a new Saudi Arabia coming on-stream every three years. A peak in conventional oil production before 2030 appears likely, and there is a significant risk of a peak before 2020.

Traditional fossil-fuel resources face serious supply constraints and an oil supply crunch is likely in the short-to-medium term.

While the vast majority of investment in the energy transition will come from the private sector, governments have an important role in delivering policies and measures that create the necessary investment conditions and incentives.

Geothermal in Hawaii

Geothermal is one of Hawaii's main energy building blocks. Unlike solar and wind power, it is what's called a "firm" resource—always there. Volcanic molten rock (magma) remains below Earth's crust, heating nearby rock, rainwater, and seawater that has seeped deep 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.

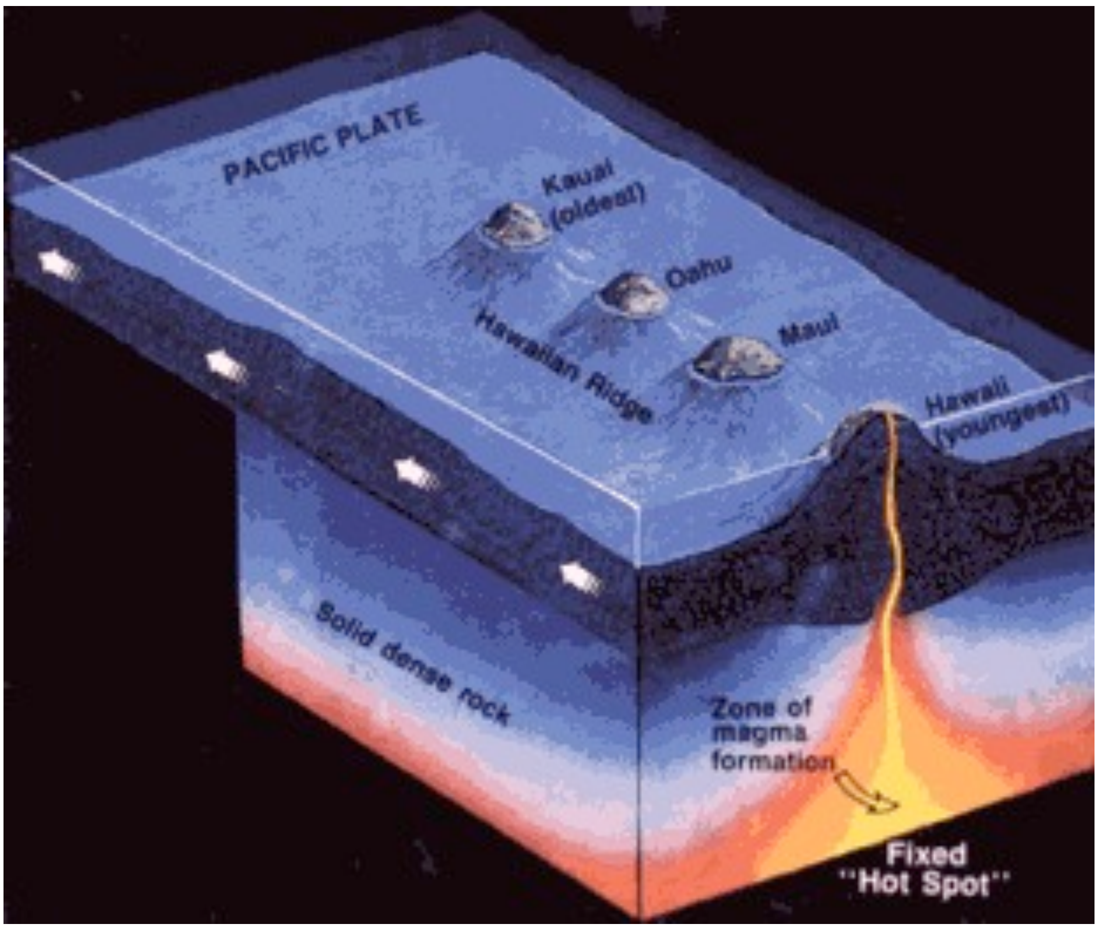


Once geothermal waters reach the surface, fresh-water steam is created and sent to the power plant driving turbines that in turn drive a generator to produce electricity. Afterward, the brine and gases are re-injected back into the injection zone below the water table. Binary-cycle plants are the most advanced. Their closed-loop circulation system means that no excess gases or fluids reach the open air. PGV's power plant utilizes the closed-loop binary system.

The Puna Geothermal Venture facility is the first and only commercial scale geothermal plant in Hawaii. It produces about 30 megawatts of power, or 20 percent of the island's needs. That's enough electricity for 30,000 homes. Today, PGV saves Hawaii Electric Light Co. (HELCO) more than 144,000 barrels of oil a year. Despite being restricted to the Big Island of Hawaii, geothermal produces about 31 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. A greater awareness of geothermal's potential is needed.

Geothermal Development in Hawaii



Geothermal resources

The Hawaiian Islands lie above a geological *hot spot* in the earth's mantle that has been volcanically active for the past 70 million years, with the island of Hawaii (Big Island) having the most recent activity. The Big Island has great potential for geothermal energy resources, both for electrical generation and direct utilization. Geothermal power potential on the Big Island has been estimated at between 500 and 700 Megawatts.

Geothermal interest was 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 helps to make the island less dependent on imported energy.

Puna Geothermal Venture Power Plant

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; it is capable of producing about 30 MW of power. Puna Geothermal Venture provides nearly a quarter of the power consumed on the Island of Hawaii.

In 2001, Puna Geothermal Venture was chosen to operate the Puna Geothermal Research Center (Noi'i O Puna) facility by the Natural Energy Laboratory of Hawaii Authority. Puna Geothermal Venture continued power production while also developing new production capabilities without drilling new wells. PGV can market facilities to transfer surplus heat from their geothermal facility for geothermal related businesses of local entrepreneurs.

Puna Geothermal Venture facilities

Energy Storage and Transportation

The 7th annual NH3 Conference was held in Detroit, Michigan. NH3 is ammonia and it's "the only realistic energy solution that makes sense," according to Matt Simmons of the National Petroleum Council, the Council on Foreign Relations and founder of the Ocean Energy Institute.

Curtailed geothermal should be used to manufacture hydrogen, then further synthesized to ammonia, which is denser and has more practical applications. H2 is less practical as an energy carrier due to it's volumetric density compared to NH3. There are three atoms of hydrogen in ammonia's molecule, rather than two. Therefore, it's a third more energy dense when transporting. And, it can be transported through the propane infrastructure at relatively low temperature and pressure. With a little modification, NH3 can be used to run internal combustion engines. The largest company in the world that converts engines for propane use is now working on commercially modifying engines so that they can use NH3. They focus on fleet vehicles, like school buses, emergency vehicles, public safety and transportation, etc.

Rather than using hydrocarbons to make NH3, as is done now, we can use electricity for hydrolysis to separate out the hydrogen and oxygen from plain water; then take "N" (nitrogen) from the air to make NH3. Cheap electricity from "off peak" geothermal power would make this cost-competitive as oil prices rise. Considering the recent Lloyd's of London White Paper telling its business clients to be prepared for $200/barrel oil by 2013, it is prudent to be self-reliant.

The three ingredients for NH3 are: geothermal for cheap electricity, water for the hydrogen, and air for the nitrogen. All three are in abundant supply on the Big Island.

If we do more geothermal, we can get cheaper electricity for all. And, as the NH3 technology develops, we position ourselves and future generations to benefit from new industries and employment opportunities.

NH3 is simply ammonia and its safety issues are easily overcome. Catalytic converters can take care of greenhouse gases. Researchers are working on making the combustion more efficient.

Guy Toyama (Energy Future Hawaii) said he believes we should be burning H2 as fuel and using NH3 as the H2 carrier. That's why it it's important to have an ammonia cracker, like Shaun Grannell was demonstrating at the conference: an engine running on pure H2. A pipe on the outside stripped the NH3 to H2 + NO, NO2. Hydrogen flame speed is quicker, so you can more easily convert an internal combustion engine to run on H2.

VII. 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.

It is the industrial nature of geothermal energy that creates legitimate barriers to exploration and exploitation of this energy source. 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. New geophysical data is needed. Major policy changes should be accompanied by data that decision makers can trust and rely on. The data available to Hawaii's energy planners and

decision makers is very outdated. Some assessments go back to the 1970's and 1980's and will unnecessarily obfuscate the areas of conflict with future energy exploitation.

2. A realistic assessment of how much energy is needed and how soon it is needed must be funded. While some proponents already conclude that 100 - 200MW of commercially viable geothermal energy should be in place and dispatchable to the HELCO grid by 2015, it just won't happen without massive governmental and corporate intervention.

3. 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.

4. If there is any expansion of geothermal facilities, this Working Group should conduct a review of the air quality/hydrogen sulfide emissions rules, noise regulations relating to geothermal exploration, drilling operations, and production operations. Those are the environmental impacts that caused great alarm and objection in years past. Is anything different now? Are there new rules, regulations, more enforcement personnel and programs, etc.?

5. DLNR participation in this Working Group 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 Kawaihae region.

6. Our committee should hear 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?

7. What role does the County have in responding to these issues? Hawaii County Civil Defense got involved in the 80's and 90's and there have been changes in their personnel. What is the agency's state of readiness to handle new and remote industrial activities?

8. What kind of subsidies will be considered for future increments of geothermal energy? People affected by industrialization and its pollutants will again ask for *contested case hearing* rights. We can expect this issue to continue to be contentious and resolution in court or dispute-mediation settings will do much to dispel direct action by citizens.

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 loose work importing supplies for petroleum-based plants. Funding for a study is needed and the Working Group recommends the legislation make it available.

An oft-repeated concern by neighbors of 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. A response plan consistent with Hawaiian Civil Defense and federal EPA standards must be developed and promulgated throughout the neighboring communities.

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. A general discussion concluded that the contested case hearing is not recommended at this time.

Respect for Pele

During their voyages, sea-faring Hawaiians noticed the differences in erosion, soil formation, and vegetation and recognized that the islands to the northwest were older than those to the southeast. This idea was handed down from generation to generation in the legends of Pele. Pele, the Goddess of Volcanoes, originally lived on Kauai. When her older sister Namakaokahai, the Goddess of the Sea, attacked her, Pele fled to the Island of Oahu. When she was forced by Namakaokahai to flee again, Pele moved southeast to Maui and finally to Hawaii, where she now lives in the Halemaumau Crater at the summit of Kilauea Volcano. The mythical flight of Pele from Kauai to Hawaii (which alludes to the eternal struggle between the growth of volcanic islands from eruptions and their later erosion by ocean waves) is consistent with geologic evidence obtained centuries later that clearly shows the islands becoming younger from northwest to southeast.

Geothermal development should not interfere with local customs regarding Pele, but rather become integrated with the life-giving forces that nature supplies. The goddess of the sea yields up her bounty to the benefit of islanders and so might the goddess of volcanoes.

Public Relations

The development of geothermal energy in the Kilauea East Rift Zone has stirred a significant amount of controversy. The experimental HGP-A power plant (1976-1989) was not perceived as a "good neighbor" due to emission releases, the extent of brine ponds beyond the plant boundaries, and an unkempt appearance of the plant itself because of limited maintenance. Further exploration was opposed, often vehemently, by people expressing concern over various issues, including impacts on Hawaiian cultural and religious values, potential geologic hazards, public health, and loss of native rainforest, as well as changing the rural nature of Puna. During the establishment of the Puna Geothermal Venture plant, an episode of planned open venting and a number of uncontrolled steam releases stimulated the evacuation of some nearby residents and enhanced fears that the resource could not be safely tapped.

The PGV plant has been operating since 1993; most residents have accepted it as part of the grid power supply. However, there is continued concern about health and environmental issues among some residents near the plant which have resulted in investigations by the US Environmental Protection Agency and a program documenting residents' health problems, which some residents attributed to geothermal emissions. The relationship between PGV and its neighbors appears to have improved with better communication between the company and the adjacent residents.

Geothermal wells are sometimes vented intentionally for a few hours to clear the well and pipelines resulting in a temporary release of steam and abated gases. These events can be noisy for a short time and, in addition, the power plant equipment (cooling tower fans and pumps) do emit continuous low-level noise during normal power plant operations. Hence, some impact on the community from power production is inescapable and serves as a continuous irritation to those who feel that their environment has been invaded by industrialization.

A more intangible objection was also raised by some who claimed that the development of geothermal power was interfering with native Hawaiian worship of Pele. These objections were taken as far as the U.S. Supreme Court, who found that geothermal development does not interfere with religious freedom.

Decades have passed since many of these events occurred. Puna Geothermal Venture was able to bring a 35-megawatt power plant online – after many delays and much greater costs than had been anticipated by their original investors. Although technical challenges remain a significant concern in the operation of this facility, it has managed to produce power with a minimum of steam releases into the community and a minimum of public controversy.

Resistance Groups

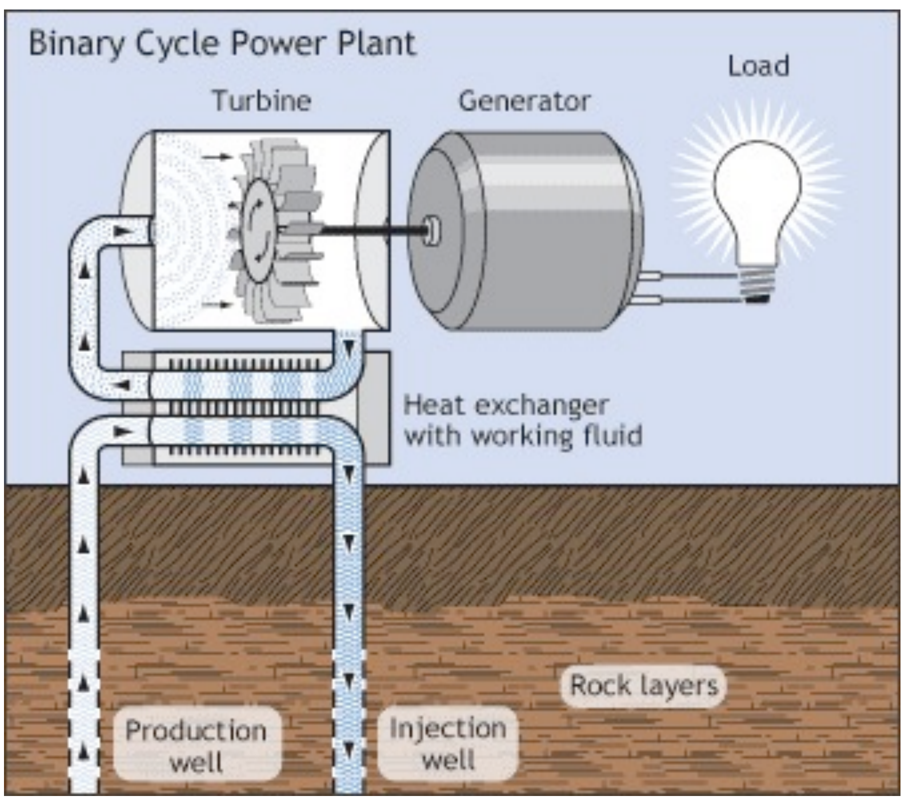
There is still resistance to using geothermal energy by some members of the local community, even though many of the issues that triggered adverse reactions have been (and continue to be) addressed by government and PGV. However, there are well organized groups (such as the Pele Defense Fund, Rain Forest Action Network and other community organizations) that continue to express concern about the abilities of the government and developers to provide socially and environmentally sound geothermal power. Further, the level of support given by the state's political establishment to expansion of geothermal capacity (there is presently only funding for one geothermal staff person at the state level) remains vanishingly small.

Advantages

From an environmental standpoint, it's difficult to find a more attractive option than geothermal power. Because the system is essentially a closed-loop; there are virtually no emissions, making it arguably the cleanest choice for energy production. Although other power sources, such as solar panels, also have no emissions, the treatments used in production of solar panels are much more environmentally degrading than building a geothermal plant to supply a comparable amount of energy.

From a land use perspective, geothermal is also incredibly positive as an energy source. While coal power plants require roughly nineteen acres per MW, and nuclear power plants require between five and ten acres per MW, geothermal plants can use as little as one acre per MW, and rarely more than eight acres per MW. Unlike many other plants, they are also very scalable, allowing small plants to be built to supply geothermal power to rural areas, and enormous plants to be built for metropolitan areas.

Geothermal energy is also largely renewable, as the reservoir of heat from the inside of the Earth is massive when compared to the amount used in power generation, even if scaled up enormously. Unlike other renewable sources, like solar panels or wind turbines, geothermal energy is also very dependable. Because the energy source is the heat from the Earth itself, which fluctuates very little, energy is always available. This means that a geothermal plant can operate at around 90% of capacity year round, without experiencing fluctuations based on sunlight or seasonal wind patterns that plague other alternative sources.



Disadvantages

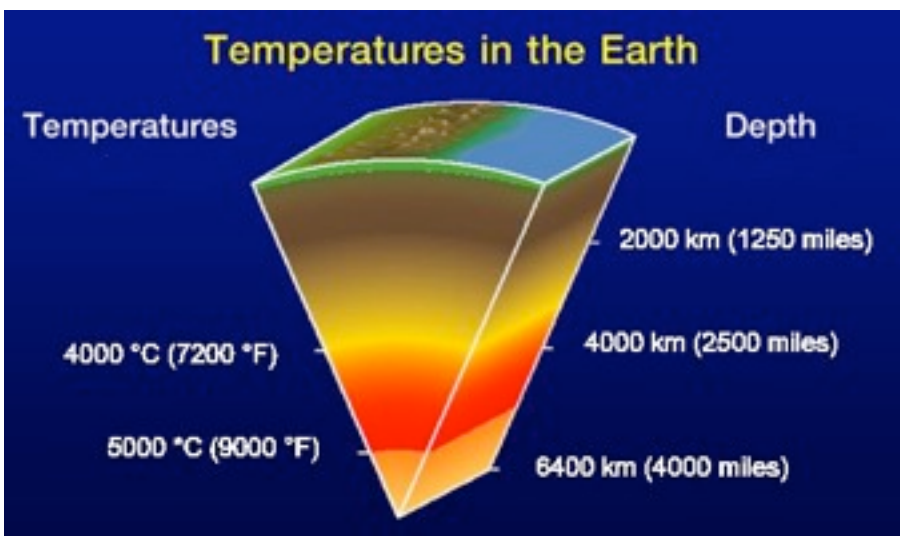
There are three major disadvantages of geothermal energy: renewability, infrastructure requirements, and location.

The drain on the earth's resources is one of the largest disadvantages of geothermal energy. Once the heat source starts to cool down, there is no way to reverse it. Although these types of energy plants can provide stable energy for an extended period of time, there is a definite end date. In order to replace that energy source, a new location would need to be identified and a new plant built.

The equipment, staff, infrastructure, and training required to create a geothermal energy plant is a significant investment of both cash and equipment. Once the energy is harnessed from the ground, it needs to be converted into electricity and transported to electricity transmission stations. An entire network of electricity towers, stations, and switches are required to move the power from the geothermal plant site to the consumer.

Skilled staff need to be recruited and relocated to the plant location. The ideal location for a geothermal energy station is quite remote, which adds to the cost of the project. Sometimes resources and facilities to house and support a large staff are required.

Further exploration of the risks and benefits of geothermal energy are required before it can be utilized as a reliable source of energy.



VIII. 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 the Hawaiian Legislation 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.

As described in section VI. The Cost of Energy, Energy Storage and Transportation, 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 can become an important industry on the island that has the potential to become a major export business, too. 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. Implementing the transition is strongly recommended.

Renewable Portfolio Standard

A Renewable Portfolio Standard (RPS) is a policy to encourage the use of renewable energy sources. It sets minimum targets for the production of electricity generated from renewable resources. Electric utilities in Hawaii are *regulated monopolies* and operate without competition, but must follow rules set by the Public Utilities Commission. By adopting a renewable portfolio standard, the use of renewable energy becomes one of those rules.

IX. 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 MW (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), Lalamilo Windfarm (1.5 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.

Scope of Study

HELCO will be responsible for performing high-level transmission studies to evaluate the expansion of geothermal generation. These studies will provide a general evaluation of transmission requirements for additional geothermal generation, but will not be equivalent to the detailed interconnection study required for a specific project. Because there can be numerous scenarios for expansion -- and, there are costs associated with each scenario evaluation -- the sub-committee will evaluate two scenarios.

Scenario 1: Expansion of 50 MWs of geothermal generation on the east side of the island near or at the Kilauea Rift Zone.

Scenario 2: Expansion of 50 MWs of geothermal generation on the west side of the island near or at the Hualalai Resort.

HELCO will fund the studies as part of its normal planning budget.

Timeline

Activity:	*Completed by:*
Definition of Scenarios	December 15, 2010
Performance of load flows and simulations	February 15, 2011
Cost estimates	March 15, 2011
First draft of report	June 15, 2011
First draft comments	July 15, 2011
Revisions	August 15, 2011
Final draft of report	September 15, 2011
Integration with Working Group report	November 15, 2011

X. Geothermal as Primary Energy Source

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 consume most 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 un-utilized 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 the Hawaiian Island'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 have been negotiating a contract for an additional 8 MW of capacity for a number of years. If finalized and 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. However, there is presently no demand for this amount of power on the Big Island.

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.

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.

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

XI. 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 the Hawaiian Legislature 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. Over the last seven years, however, there is a trend of increasing revenues.

Fiscal Year 2001

Department of Land and Natural Resources (50%) $358,829.00
County of Hawaii (30%) $215,297.40
Office of Hawaiian Affairs (20%) $143,531.60

Total $717,658.00

Fiscal Year 2002

Department of Land and Natural Resources (50%) $238,979.00
County of Hawaii (30%) $143,387.00
Office of Hawaiian Affairs (20%) $95,592.00

Total $477,958.00

Fiscal Year 2003

Department of Land and Natural Resources (50%) $41,147.50
County of Hawaii (30%) $24,688.50
Office of Hawaiian Affairs (20%) $16,459.00

Total $82,295.00

Fiscal Year 2004

Department of Land and Natural Resources (50%) $339,082.50
County of Hawaii (30%) $203,449.50
Office of Hawaiian Affairs (20%) $135,633.00

Total $678,165.00

Fiscal Year 2005

Department of Land and Natural Resources (50%) $484,990.00
County of Hawaii (30%) $290,994.00
Office of Hawaiian Affairs (20%) $193,996.00

Total $969,980.00

Fiscal Year 2006

Department of Land and Natural Resources (50%) $927,697.00
County of Hawaii (30%) $556,618.20
Office of Hawaiian Affairs (20%) $371,078.80

Total $1,855,394.00

Fiscal Year 2007

Department of Land and Natural Resources (50%) $919,541.50
County of Hawaii (30%) $551,724.90
Office of Hawaiian Affairs (20%) $367,816.60

Total $1,839,083.00

Fiscal Year 2008

Department of Land and Natural Resources (50%) $1,349,233.50
County of Hawaii (30%) $809,540.10
Office of Hawaiian Affairs (20%) $539,693.40

Total $2,698,467.00

Fiscal Year 2009

Department of Land and Natural Resources (50%) $1,568,743.49
County of Hawaii (30%) $941,246.10
Office of Hawaiian Affairs (20%) $627,497.40

Total $3,137,486.99

Grand Total of Royalties to Fiscal Year 2009 .... $12,456,486.99

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.

Benefits of geothermal energy have been known for many years

Macaque apes use hot-springs to survive in winter

Appendices

Appendix A

Senate Concurrent Resolution 99
Senator Russell Kokubun

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THE SENATE.
TWENTY-FIFTH LEGISLATURE, 2010.
STATE OF HAWAII.

S.C.R. Number 99. FEBRUARY 26, 2010.

==

SENATE CONCURRENT RESOLUTION.

REQUESTING THE ESTABLISHMENT OF A WORKING GROUP TO ANALYZE THE POTENTIAL DEVELOPMENT OF GEOTHERMAL ENERGY AS THE PRIMARY ENERGY SOURCE TO MEET THE BASE-LOAD DEMAND FOR ELECTRICITY ON THE BIG ISLAND.

WHEREAS, in 1881, King David Kalakaua visited Thomas Edison in New York to discuss extracting power from Hawaii's volcanoes and using underwater cables to carry power between islands; and

WHEREAS, at the time, his strategy did not prove to be feasible, and hydropower was used to generate electricity to light Honolulu; and

WHEREAS, today, technology advances make geothermal energy not only feasible, but a top source of renewable energy; and

WHEREAS, geothermal energy is a more reliable source of energy than solar or wind energy, because when the wind does not blow and the sun does not shine, the heat from the volcano continues to produce a steady flow of power; and

WHEREAS, Hawaii's ratio of renewable energy generation (ten percent) to fossil fuel generation (ninety per cent) ranks third in the nation; and

WHEREAS, the United States Department of Energy has indicated that Hawaii is one of the best positioned states for renewable energy potential; and

WHEREAS, the United States Environmental Protection Agency asserts that greenhouse gases threaten public health and science overwhelmingly shows greenhouse gas concentrations are at unprecedented levels due to human activity; and

WHEREAS, there is irrefutable evidence that global warming is real and occurring at an alarming rate, with rising sea levels and stronger and more frequent storms; and

WHEREAS, the designation and establishment of geothermal resource sub-zones more than twenty-five years ago needs to be reviewed to reaffirm or amend the original feasibility assessments; and

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

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

WHEREAS, the Hawaii Clean Energy Initiative aims to meet seventy per cent of the State's energy needs through renewable sources by 2030; and

WHEREAS, geothermal energy is efficient and stable, and has long-term viability to help Hawaii meet its 2030 goals, reduce its contribution to global warming, and create a sustainable energy market; and

WHEREAS, as a proven source of reliable firm capacity, geothermal energy has great potential to be the primary source of energy to meet the Big Island's base-load demand, generating the amount of power required to meet minimum electricity demands based on reasonable expectations of customer requirements; now, therefore,

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; and

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

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

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; and

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; and

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 base-load demand on the Big Island, including an analysis of community, environmental, and economic benefits; and

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; and

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; and

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; and

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.

Appendix B

Composition of the Commission

The working group consists of eleven members with the Mayor of Hawaii County designating the chairperson, including:

1. The Hawaii County Energy Coordinator, or designee
Member: Richard Ha, President of Hamakua Springs Country Farms, co-chair of Working Group

2. One member designated by Hawaii Electric Light Company
Member: Jay Ignacio, President of HELCO

3. One member designated by the Big Island Labor Alliance
Member: Wallace Ishibashi, Jr., Big Island Labor Alliance, co-chair of Working Group

4. One member designated by the Hawaii Island Economic Development Board, Inc.
Member: Barry Mizuno, HIEDB

5. One member designated by the Chairperson of the Public Utilities Commission
Member: Carlito P. Caliboso, Chairman of the Public Utility Commission

6. The Hawaii Island Office of Hawaiian Affairs Trustee, or designee
Member: Robert Lindsey, Hawaii Island OHA trustee

7. One member designated by the Director of Business, Economic Development, and Tourism
Member: Ted Peck, the State Energy Administrator
Department of Business, Economic Development & Tourism

Alternate: Andrea T. Gill, Renewable Energy Specialist, State of Hawaii
Department of Business, Economic Development & Tourism
Strategic Industries (Energy) Division

8. One member designated by the Chairperson of the Board of Land and Natural Resources
Member: DLNR- Did not send a representative

9. One member who is a representative of a non-profit, environmental group to be selected by the President of the Senate
Member: Nelson Ho, Chair of the Moku Loa Group (Hawaii Island), Sierra Club

10. One member who is a representative of a cultural organization to be selected by the Speaker of the House of Representatives
Member: Patrick Kahawaiola'a, President of the Keaukaha Community Association

11. One member representing West Hawaii to be selected by the Mayor of Hawaii County
Member: Jacqui Hoover, executive Director HLPC-West Side Representative

Recorder: Kaycie Carter, Clerical Services Supervisor, Office of the Mayor

Appendix C

Geothermal Working Group Minutes
Recorder: Kaycie Carter

Minutes of Geothermal Working Group meeting held June 6, 2010

Minutes of Geothermal Working Group meeting held July 15, 201

Minutes of Geothermal Working Group meeting held August 26, 2010

Minutes of Geothermal Working Group meeting held October 11, 2010

Minutes of Geothermal Working Group meeting held November 8, 2010

Appendix D

Activities to Date

Geothermal Working Group members attended monthly round-table discussions

Geothermal Working Group members prepared an Interim Report

Geothermal Working Group members toured HELCO power plant July 15, 2010

Geothermal Working Group members toured PGV power plant August 26, 2010

Richard Ha attended the **7th Annual NH3 Fuel Conference** in Detroit, MI Sept. 26–28, 2010

Richard Ha attended the **2010 ASPO-USA Peak Oil Conference**: The Future of Oil, Energy and the Economy in Washington, D.C. October 7-9, 2010

Energies **2009**, *2*, 25-47; Review **What is the Minimum EROI that a Sustainable Society Must Have?** by Charles A. S. Hall, Stephen Balogh and David J. R. Murphy

Wallace Forbes, 09,13,10; Review **Bracing For Peak Oil Production By Decade's End**, and interview with Charles Maxwell, senior energy analyst.

Review Platts News Service report by Leslie Moore, on the **ASPO Conference in Washington, DC - Peak Oil**

Analyze the latest material on emerging risk in the energy sector by **Lloyd's of London Insurance**; **360 Risk Insight**, a peer-reviewed White Paper by Antony Froggatt and Glada Lahn.

Co-chairs Wallace Ishibashi and Richard Ha participated in panel discussions in Kona and at the University of Hawaii, Hilo.

Co-chair Richard Ha participated with Kale and Robbie Alm and a Native Hawaii Legal Corp attorney on a geothermal panel at the Association of Hawaiian Civic Clubs in Kona.

Kanoe Wilson, University of Hawaii, Office of Student Affairs, First Nations' Futures Program Fellowship. Kamehameha Schools instituted program to improve management of First Nations' assets. Promote awareness through education of risks and rewards of developing geothermal; outreach which is still continuing.

Co-chair Richard Ha gave presentations to the Waimea and Keaukaha Community Associations, the Rotary Club of Waimea, and the Lions Club of Hilo.

Co-chair Wallace Ishibashi, Mike Kaleikini, Mililani Trask and co-chair Richard Ha appeared on Solar Radio. Richard Ha has been appeared on that program discussing geothermal three times.

Appendix E

Individuals & Organizations Speaking to the Working Group

Kristine Kubat, a community and environmental advocate said that more public discussion about geothermal energy was needed and described herself as a watchdog. She said that no overtly pro-geothermal information should come out of the Working Group's report. She said a community apology is needed; she proposed using the Pahoa Community Center. Also, there are rumors of the dumping of chemical toxins at PGV.

Jon Olsen, a member of the Puna community, reported that the decisions made about energy development are based on political expediencies and not based on scientific or economic data. He stated that a professor at MIT is of the opinion that solar energy is the best choice. Mr. Olsen provided handouts to the Geothermal Working Group. 87 property owners petitioned to be removed from geothermal subzone classification.

Moani Akaka, a member of the Puna community, reported the geothermal well had a caustic blowout in early days. She has reservations about geothermal. However, If it is to be done, it must be done properly to avoid the problems of the past.

Steve Phillips, a member of the Puna community, had a bad experience with geothermal before. He said that the law should be changed to permit a contested case hearing. Any new development that impacts the community must uphold the rights of those in the neighborhood. He stated that geothermal gases poisoned his son in his crib. He stated that he lost his marriage because of geothermal. His property values went down because of geothermal. He said he wrote rules for a geothermal asset fund that were never used. How will the mess of a decommissioned plant be funded when it needs to be dismantled? That is what the asset fund is for. He will do everything in his power to halt geothermal development unless the community has a contested case hearing. The community led to improvements over the poorly designed and built experimental well.

Robert Petricci, lived in the neighborhood during the development of geothermal and was evacuated years ago when there was an open venting. He wants a contested case hearing. There will be problems if geothermal is built where people live. Also, geothermal developers must not cut corners during construction.

Steve Dearing, project manager of Kealoha Energy, reported that geothermal development would lead to lower electrical rates and new jobs. Kealoha Energy is proposing a new 30 MW facility in Puna.

Patricia Brandt, **Mililani Trask**, and **Roberta Cabral** of Innovations Development Group (IDG) and Indigenous Consultants (IC) made a presentation to the Geothermal Working Group.

Donald M. Thomas - geologist - U of HI, Hilo
dthomas@soest.hawaii.edu
Gave a presentation to the Geothermal Working Group. Big Island's Kilauea is located above a *hot spot* of Earth. It holds the greatest geothermal potential. The magma flows out from the reservoir into two rift zones; they either erupt or are stored as dikes intruded into rift zones -- storing heat and transferring it to underground water. Zoning of land is done by legislation -- overlaying existing zoning -- assessed every 5 years -- to determine feasibility of geothermal per geophysical and environmental / political considerations. The last geophysical surveys were done in the 1970's and 1980's; new surveys with modern equipment and techniques will yield more reliable data. However, since the environment determines people's lives and culture, there is a balance between resource mining and the conservation of pristine lands.

Kanoe Wilson - Office of Student Affairs - U of HI, Hilo
suganuma@hawaii.edu
Gave a presentation to the Geothermal Working Group. First Nations' Futures Program Fellowship. Identify the cultural impacts of energy development. Kamehameha Schools instituted program to improve management of First Nations' assets. Promote awareness through education of risks and rewards of developing geothermal. Suggested "listening tours" island-wide: community associations, Kupuna Advisory group, Kanaka Council, and church groups.
papahulihonua.com

Guy Toyama - Executive Director - Friends of NELHA (Natural Energy Laboratory of Hawaii)
President and CEO of H2 Technologies, Inc.
guy@EnergyFutureHawaii.org
Gave a presentation to the Geothermal Working Group. The Natural Energy Laboratory of Hawaii advocates the use of excess geothermal energy - energy in addition to what HELCO uses - to produce ammonia through electolyzers. Ammonia is a way to store hydrogen from electrolysis.

There are multiple benefits to creating ammonia from geothermal plants: fertilizer, fuel for cars, fuel for buses, fuel for electrical generators (easily transportable in this form), and during off-peak hours, curtailment of plant production, which would mean waste, can be avoided if facilities produce ammonia via electrolysis.

James "Mitch" Ewan - Hydrogen Systems Program Manager
Hawaii Natural Energy Institute ewan@hawaii.edu, 1680 East-West Road, POST 109, Honolulu, HI 96821
OFFICE: 808-956-2337
MOBILE: 832-212-6129
FAX: 808-956-2336
Presentation at the third Geothermal Working Group meeting 8/26/10. Hawaii is the most petroleum-dependent state in the union. The County of Hawaii spends $1billion per year on petroleum. The Energy Initiative mandates that 70% of Hawaii's energy be clean by 2030. 60% of municipal waste can be converted to fuel. The GM Equinox runs on hydrogen. Hydrogen can be used to store energy. The state has a $10million fund for entrepreneurs who develop clean energy. Clear Fluids is a fuel company that develops hydrogen fuel. HNEI uses an electrolyzer. Remote oration is possible over the Internet and is in use on Big Island. Volcanoes Park diesel buses will be replaced with fuel cell buses. Fertilizer is a by-product of the conversion and reduces agricultural costs. Fish farms can use the oxygen from electrolysis. 12,000 kWh per ton of NH_3.

Appendix F

Q&A with HELCO

On February 19, 2010, the Hawaii Public Utilities Commission (PUC) approved a new method for setting electric rates designed to encourage a clean-energy economy for Hawaii.

Under the new "decoupling" method, electric revenues would be de-linked, or "decoupled," from the amount of electricity sold. Under that agreement the utilities committed to much more aggressive clean energy goals -- including increasing the proportion of renewable energy in Hawaii from 25% by the year 2020 to 40% by the year 2030 (among the most aggressive goals in the nation). PUC will be adding new energy efficiency goals, implementing a feed-in tariff to speed the addition of renewable energy projects, and pursuing a smart grid that includes advanced metering to give customers more options such as residential time-of-use electric rates. The concept of decoupling, which has been adopted for utilities in California, Vermont, New York and many other progressive jurisdictions, was also endorsed by environmental and renewable energy groups.

Under a decoupled system, the PUC approves a revenue level based on the services it authorizes the company to undertake on behalf of customers. Rates are then adjusted based on varying sales levels, allowing the utility to continue recovering the costs of providing those services, but not earn additional profit from higher sales. This model provides greater support for energy efficiency and conservation and achievement of Hawaii's clean energy goals.

Question: With the most recent ruling by the PUC to decouple profits and energy sales, is HELCO willing to bring more geothermal electricity to the HELCO grid?

Answer: Decoupling removes the relationship between revenue and kWhr sales (a kilowatt hour is power consumption of 1,000 watts for 1 hour). It helps the utility to support energy efficiency programs and customer self-generation. Decoupling helps to reduce energy use and decrease the need for central generation so less -- not more -- geothermal energy would be needed in the short term. Long-term geothermal energy would be a good option to serve expected increased energy needs of the Big Island.

Rates also would increase or decrease between formal rate cases (based on independent cost indices) and adjustments that would allow HELCO to recover PUC-approved capital additions.

Question: What technical requirements would you impose on the developer for grid reliability and safety?

Answer: HELCO is going through this process with PGV for their additional 8 MWs. We expect geothermal energy to be dispatchable, have regulating capability, have comparable inertia to conventional steam plants, and ride through system disturbances comparable to other conventional units.

Question: Is there a way to accept 60 megawatts of geothermal electricity from one location knowing PGV is situated in a lava inundation zone?

Answer: I assume the location you are speaking of is the Kilauea Rift Zone. As part of the working group assignment to evaluate system facility needs to integrate geothermal, HELCO will be studying 2 scenarios. The first would be the addition of additional geothermal energy near the existing PGV facility and the second will be additional geothermal energy on Hualalai. I do not want to comment prematurely before those studies are complete.

Question: Can more wind or solar generation or other renewable systems be incorporated into the HELCO grid?

Answer: We have not committed to additional wind energy at this time though there are still opportunities to add more wind energy. We need to find economical technologies to address the variability of wind before doing so. We are doing a battery installation in North Kohala to study using a battery to mitigate the fast variations of wind energy. We are also doing studies to learn more about forecasting of wind. This is especially difficult on an island since installing monitoring stations offshore would be expensive. We are also making improvements to the controls on our conventional units to be more responsive to the variations to the system that wind energy introduces. Solar generation also introduces challenges for the utility to address both on a circuit level and a system level. We currently are continuing to add solar energy but need to use new technologies to incorporate larger amounts. We are engaged in studies to explore and test those new technologies. Installations are occurring faster that we can complete the studies.

Question: With a growing demand for electric cars for transportation, will the demand for electricity grow more quickly than earlier predicted? If so, any estimates?

Answer: The forecast is that electric cars will take many years to become a significant part of the transportation sector. I hope those forecasts are incorrect. In any case we need to be prepared for increasing electric car use and be ready to make improvements to the electric grid if necessary. With decoupling the increase in demand for electricity can lead to lower prices. It would also allow for more renewable energy interconnection to the grid.

Appendix G

Energy Return On Investment by Dr. Charles A. S. Hall

Excerpts from an article published in *energies* ISSN 1996-1073, www.mdpi.com/journal/energies January 23, 2009

What is the Minimum EROI that a Sustainable Society Must Have?
Charles A. S. Hall, Stephen Balogh and David J. R. Murphy

Economic production and, more generally, most global societies, are overwhelmingly dependent upon depleting supplies of fossil fuels. There is considerable concern among resource scientists and many economists that decisions made about the future of energy, based on today's prices, could have dire consequences. The rise in petroleum prices between 2005 and 2008 that lead to the related market collapse of 2008 provided one indication of the short-comings of future predictions based on current market prices.

A different method used to calculate the cost / benefit ratio of energy resources is: Energy Return On Investment (EROI). It provides a more rigorous approach to examining advantages and disadvantages of different fuels and also offers the possibility to look into the future in ways that markets seem unable to do. One important goal of the Geothermal Working Group Interim Report 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. We surmise that for any system to survive, grow, and thrive, it must gain substantially more energy than it uses in obtaining that energy. Thus, Hawaii must abide by the principles that can be calculated using the Law of Minimum EROI for fossil fuel, which has been calculated at about 3 to 1 (the cost to drill, refine and deliver petroleum is three times greater than the benefit of use in farming, driving, producing electricity, etc.).

Today's prices are not influenced by tomorrow's conditions; the most abundant fuels will be less available -- for either geological (depletion) or political reasons -- in the future. In addition, current prices of energy in the U.S. are greatly influenced by various subsidies. The end of cheap oil might be, or soon might be, upon us. Meanwhile, gasoline prices, although high in nominal terms, just about peaked in 1981. Corrected for inflation, what we now pay for gasoline in a year is a smaller proportion of our income. Given that our island society is overwhelmingly dependent upon oil, this is cause for concern. The price at the pump or the price of a barrel today is a false indicator of true reserves and future market costs. Current conditions are an unreliable basis for projections and planning.

Net energy analysis is called the assessment of energy surplus, energy balance, or, energy return on investment (EROI). EROI is calculated from the following simple equation:

EROI = Energy returned to society vs. Energy required to get that energy

For most fuels, especially alternative fuels, the energy gains are reasonably well understood, but the boundaries of the denominator, especially with respect to community reaction and environmental issues, are poorly understood and even more poorly quantified. Survival, comfort, wealth, art and even civilization itself is a product of surplus energy. The ability of a given society to divert attention from life-sustaining needs, such as agriculture or the attainment of water, towards luxuries such as art and scholarship is based on the quantity and quality of surplus resources. Indeed, humans could not possibly have made it this far, or even from one generation to the next, without there being some kind of net positive energy.

Energy comes from many sources – from imported and domestic sources of oil, coal and natural gas, as well as hydropower and nuclear, and renewable energy – increasingly from wind, solar, geothermal, etc. Most of these are cheaper per unit energy delivered than oil. Globally, for every barrel of oil invested in seeking and producing more oil, some 20 barrels are delivered to society. Thus, fossil fuels still provide a very large energy surplus, obviously enough to run and expand the human population and the very large and complex industrial societies around the world.

That's the good news. The bad news is that 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. Either technology, the market and economic incentives will continue to find oil to replace that which we have extracted, or the prices will increase as oil reserves deplete and society must find substitutes when new technologies develop.

Furthermore, there is considerable evidence that, in the case of oil, we are mostly just pumping out old fields rather than replacing extracted oil with newly found oil. Globally, we are using between 2 to 3 barrels for each new barrel found. 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. This means that the question is not necessarily what the size of global oil reserves is, but rather what is the size of that portion that is extractable with a positive net energy value? In the case of alternative resources the question is: at what rate can high EROI fuels can be produced. The implications of this are obvious, huge, and make an argument for seeking substitutes earlier rather than later. But, the problem with the alternatives is to find ones with the desirable traits of fossil fuels: 1) sufficient energy density 2) transportability 3) relatively low environmental impact per net unit delivered 4) relatively high EROI and 5) producible on a scale that society demands.

Economic Realities

At the time of this writing, a barrel of oil on the New York market is about $86. Assume that the *real price* of oil, that is, the price of oil relative to other goods and services, increased to $140 a barrel. If that happened, then $2.38 trillion, one fifth of the economy, would be used to buy the oil to run the other four fifths -- *not including* the energy-extraction system itself. If the price of oil increased to $250 per barrel, about one third of all economic activity would be required to run the other two thirds. At $750 a barrel, the output of the entire economy, $12 trillion dollars, would be required to generate the money to purchase the energy required to run the economy. There would be no net output. In a real economy there would be adjustments, alternative fuels and nuances. However, this analysis does give an overview of the relation between gross and net economic activity, as well as the vital role of energy. As the price of fuel increases, its EROI declines, and there are large impacts on the rest of the economy. These impacts can be especially influential because changes in the price of energy tend to impact discretionary, not base, spending.

Oil refineries use roughly 10 percent of the energy in fuel to refine it to the form that we use. In addition, about 17 percent of the material in a barrel of crude oil ends up as other petroleum products, not fuel. So for every 100 barrels coming into a refinery only about 73 barrels leaves as usable fuel. Natural gas does not need such extensive refining, although an unknown amount needs to be used to separate the gas into its various components and a great deal, perhaps as much as 25 percent, is lost through pipeline leaks and to maintain pipeline pressure. Coal is usually burned to make electricity at an average efficiency of 35 - 40 percent. What this means is that at least 1.27 units of crude oil are added to the cost to deliver 1 unit as a fuel.

Oil weighs roughly 0.136 tons per barrel; transportation by truck uses about 3400 BTU/ton-mile. Thus, it costs about 5% of the total energy content of a barrel of oil to move it to where it is used. Now the calculation for EROI changes to about 40 percent (17 percent non-fuel loss, plus 10 percent to run the refinery, plus 10 percent extraction, plus about 3 percent transportation loss). For oil one needs an EROI at the mine mouth of roughly 1.4 to get that energy to the point of final use.

What our society needs, however, is energy services, not energy itself, which has little intrinsic economic utility. So we must count in our equation not just the *upstream* energy cost of finding and producing the fuels themselves, but all of the *downstream* energy required to deliver the service (in this case transportation): 1) building and maintaining vehicles, 2) making and maintaining the roads used, 3) incorporating the depreciation of vehicles, 4) incorporating the cost of insurance, 5) etc. Our calculation, adding in the energy costs of getting the oil in the ground to the consumer in a usable from (40 percent) plus the pro-rated energy cost of the infrastructure necessary to use the fuel (24 percent) is 64 percent of the initial oil in the ground. Thus, the energy necessary to provide the services of 1 unit of crude oil at the gas station or the electrical generator is roughly 3 units of crude oil. This cuts our EROI to 3:1 for a gallon at final use, since about two thirds of the energy extracted is necessary to do the other things required to get the service from burning that one gallon. Include the energy cost of supporting labor or compensating for environmental destruction and this ratio increases substantially. In the final analysis, even before factoring in the inefficiencies of transforming fossil fuel to electricity and delivering it to homes and businesses, the current method of electrical production is simply not sustainable.

Appendix H

Charles Maxwell, a senior energy analyst,
Interviewed by Wallace Forbes

Maxwell: 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.

The peak of production usually comes sometime between 30 and 50 years after the peak of finding oil. "The peak of discovery," as they call it. For instance, in the North Sea, the peak of discovery was in the late 1960s, and the peak of production was in the late 1990s. So it was around 30 years between the peak of finding oil and the peak production of that oil.

Forbes: From those sources in the North Sea?

Maxwell: Yes. In the United States, the actual peak of discovery was 1931, quite a bit earlier. We were the first country to actually peak in the world of oil production. Our peak of production came in late in 1970. So that was a 39-year transition from the peak of finding the oil to the peak of producing it.

Now the question remains in front of us, has the world peaked in its level of discovery and if so, how long will it take the world, if it has peaked, to reach the peak of oil output? I believe that the peak of discovery fell in the five-year interval between 1965 and 1970. So if you took it at, say, 1968, and then you added 50 years, you would get to 2018.

Forbes: Is technology reducing the time between finding and producing oil?

Maxwell: Technology is trying to give us the ability to produce more out of a giant field. In the early days we only produced about 25%. Today we're producing about 40% of the oil in place when a field is found. These numbers are gaining rather slowly now. What's happening is that the increase in the world's population and greater use of oil in transportation, particularly in the emerging countries, is working to lift oil demand, and that spurs us to drain a field more quickly, but not necessarily to get a higher proportion of oil out of it. So we have technology improving production capability, but actually taking the oil out faster rather than getting much more out. I cannot tell you whether we are lengthening the life of a field very much in these times. It's a slow process, at best.

Appendix I

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

A panel of geologists and energy analysts debated Thursday the severity and timing of an anticipated oil crisis, with one saying during a Washington briefing that crude oil production has now peaked.

"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. "The size of accumulation [of oil] is not equated to the rate of production," he said. Frank Rusco, an energy director at the US Government Accountability Office, estimated some 45 years of "proven reserves," though current and future oil demand will stress supplies.

"Higher oil prices can retard economic growth and even cause a recession in the right circumstance," Rusco said at the briefing, which was organized by the Association for the Study of Peak Oil and Gas. He declined to say after the briefing what a gasoline price ceiling might be for US consumers.
"The remaining hydrocarbons will be more costly to get from underground," from a "policy perspective," Rusco said, 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." Meanwhile, "mitigation of oil dependency by transitioning into other energy sources will take upward of a decade to come into play. "Sometime after a decade, mitigation will take impact and things will start to flatten out," Hirsch said.

New reserves from Brazil and production from unconventional sources in the US will not be enough to compensate for depleting reserves, panelists said. The Ghawar oil field in Saudi Arabia, still a bright light in the petroleum world, could see a sharp and imminent decline in production, Patzek said. If Ghawar "peters out, to replace it [with production elsewhere] will be a very difficult task," he added. He estimated Ghawar's current production at between 4.5 million and 5 million barrels per day, though added that actual production figures are unknown as they are a "top secret."

Later, on the sidelines, Patzek said Ghawar could become the region's Cantarell, referring to Mexico's offshore oil field that has seen production plummet by over half from a peak 2.1 million barrels per day in the mid-2000s. Patzek said that the ongoing water-flood efforts into the

Ghawar field to stimulate production will eventually taper off. "You're injecting twice as much water into the well," he said. "Your field is watering out," Patzek said in an interview Patzek told the briefing that Norway's reserves have peaked, while he characterized the decline rate in the US Gulf of Mexico as "very high." BP's Thunder Horse well in the Gulf "has not reached its potential and it's declining faster than people thought," Patzek said. A BP spokesman was not immediately available for comment on Patzek's remarks about Thunder Horse.

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. "This is not a recovery that we're in," said Nicole Foss, a former fellow at the Oxford Institute for Energy Studies, who predicted "chaos" in foreign currency and equity markets within years. A severe deflationary plunge will contribute to a liquidity crisis among the financial sector, Foss said on a peak oil panel late last week. The meeting in Washington wrapped up Saturday.

"Oil will bottom early in this depression," Foss said. She and fellow panelist, energy analyst, Chris Martenson, predicted that foreign currency markets will become more volatile, with domino effects on global money supply. "It's not unthinkable the the US will have another financial crisis," Martenson said, adding that he gave the US a "50%" shot at having a fiscal crisis and a "50%" chance of experiencing a currency crisis. "We're going to see severe dislocations in the foreign exchange markets."

Deflation is tomorrow's problem," Foss said, adding that a lack of purchasing power will undermine price support for crude oil. Then "printing [money] is a few years off," she said. "We could see $20 per barrel and then $500 per barrel within the space of five years," Foss said. Foss runs the Agri-Energy Producers' Association of Ontario, where she has focused on farm-based biogas projects and grid connections for renewable energy. At Oxford, she researched electricity policy at the EU level, according to her website. She was previously editor of the Oil Drum Canada, where she wrote about peak oil and finance.

Speaking on the sidelines of the conference, Foss said that natural gas holds no promise as a safe hydrocarbon haven in a scenario of volatile crude oil prices. There is a "perception of a glut" of natural gas reserves and other resources from new shale plays and coal-bed methane and tight formation gas Foss said. "I would argue that this is an illusion," Foss said. The environmental cost of extracting unconventional resources "is tremendous," Foss said, adding that the energy resource "bang for buck" is unappealing. "We'll end up with natural gas price spikes, "after years of low natural gas prices," she said.

Appendix J

Strategic Risks and Opportunities for Business
Lloyd's of London White Paper

The Energy, Environment and Development Program (EEDP) at Chatham House advances the international debate on energy, environment, resources and development policy.

Author, Antony Froggatt, is a Senior Research Fellow at Chatham House. He has worked on international energy and climate issues for over 20 years.

Co-author, Glada Lahn, is a Research Fellow specializing in energy governance and development issues. She has published papers on Asian energy and is researching energy policy in the Gulf.

Overview

Independently of what happens in UN negotiating rooms, the US Congress, or multi-national corporate board rooms, Hawaii's legislature and Hawaii's businesses can take action. We can plan our energy needs, we can make every effort to reduce consumption, and we can aim for a mix of different energy sources. The transformation of the energy environment from carbon to clean energy sources creates an extraordinary challenge for our island. We can expect dramatic changes: prices are likely to rise, with some commentators suggesting oil may reach $200 a barrel; regulations on carbon emissions will intensify; and reputations will be won or lost as the public demands that big energy users and suppliers reduce their environmental footprint.

1. Energy security and environmental concerns are unleashing a wave of policy initiatives and investments that 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. Three factors render that model outdated: surging energy consumption in emerging economies, multiple constraints on conventional fuel production and international recognition that continuing to release carbon dioxide into the atmosphere will cause climate chaos.

3. China and emerging Asian economies have already demonstrated their weight in the energy markets. Their importance in global energy security will grow.

4. Energy markets will continue to be volatile as traditional mechanisms for balancing supply and price lose their power. International oil prices are likely to rise in the short to mid-term

due to the costs of producing additional barrels from difficult environments, such as deep offshore fields and tar sands.

5. Much of the world's energy infrastructure lies in areas that will be increasingly subject to severe weather. On top of this, extraction is increasingly taking place in more severe environments such as the Arctic and ultra-deep water. For energy users, it means greater likelihood of loss of power for industry and fuel supply disruptions.

6. Without an international agreement on the way forward on climate change mitigation, energy transitions will take place at different rates in different regions. Those who succeed in implementing the most efficient, low-carbon, cost-effective energy systems are likely to influence others and export their skills and technology.

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. Retail industries will need to either re-evaluate the 'just-in-time' business model which assumes a ready supply of energy throughout the supply chain.

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 for new partnerships between energy suppliers, manufacturers and users.

Introduction

This report looks at short-term (one to five years) and medium-term (five to ten years) risks to general business. It also considers longer-term (ten years plus) issues, particularly as they impact on technological and investment choices for the energy sector. While energy supply disruption is frequently the result of technical faults and strike action, we do not deal with this here, but concentrate instead on the impacts of constraints on carbon and carbon-based resources.

Historically, energy security has meant defending against supply disruption and price instability. Within this mindset, protecting the status quo is paramount. Yet dynamic trends, including the sharp rise in demand from newly industrializing economies, carbon-dioxide induced global warming and the growth of alternative energy technologies, mean that protecting traditional energy practices will make us *less secure*, and *less competitive*, in the future. This is in addition to the threat that climate change poses to energy infrastructure. These are not issues for the energy sector alone. The return to high and volatile oil prices after 2005 reinforced the link between energy prices, profits and economic stability for most businesses.

Renewable energy has moved into the mainstream and is now supplying the majority of new electricity in some regions. To increase efficiency and allow the uptake of more renewable energy, radically different infrastructures are being planned around the world. These may include local and trans-national 'smart grids' that communicate with household and industrial appliances and electric vehicles, and can send power back into the grid to help regulate demand flows.

There is little sign that energy demand will go down, with forecasts suggesting a 40% increase by 2030. This will require $26 trillion of investment - some 1.4% of global GDP. Given the global commitment to radically reduce emissions and the finite nature of conventional fossil fuel sources, a rapid movement towards a highly-efficient non-fossil energy future would seem to be the logical investment choice.

Trends

With world population growth and pressure for higher standards of living in developing countries, demand for energy will reach new heights. But how long can we rely on these ultimately exhaustible and, with the exception of uranium, C02 emitting fuels? There is now widespread acknowledgement that we are in a 'transition' period heading towards less-polluting, more-sustainable forms of energy. This involves scaling up new technologies and introducing completely different energy delivery systems.

Energy is a globalized commodity. Sudden demand pressures for certain fuels in one place, coupled with previous inadequate investment in the necessary resources elsewhere, will push up prices on the international markets. Before new models of international energy governance are developed, insecurity will encourage strategic investments by the most import-dependent countries. Together with policies to reduce subsidies and increase efficiency, these trends will drive up final consumer prices for transport, fuel, heat and electricity in the short to mid term.

Advanced economies remain the biggest consumers of primary energy per person but by 2008 non-OECD countries, led by China and India, had outstripped them in terms of the share of world demand. These consumption trajectories mean there is likely to be a tipping point in 2015 when countries in Asia-Pacific need more imported oil in total than the Middle East (including Sudan) can export.

In spite of high CO2 emissions per unit of energy (two to three times more CO2 than natural gas when burned in conventional thermal power plants), coal is the fastest growing fossil fuel. Many countries plan to increase the share of natural gas in their national energy mixes as it has lower emissions than coal and oil and is more versatile It can replace coal as a fuel for electricity generation and oil-based transport fuels in gas-to-liquid and compressed forms.

In the developing world, increasing car ownership and subsidized fuel prices will continue to drive up oil demand in the next few years. Whereas fuel-efficiency standards, taxed fuel prices and alternatives, including biofuels, reduce demand in the advanced economies. Peak oil demand (the suggestion that reductions in demand as a result of policy, technology and behavioral changes will occur before any geological driven change) is a distinct possibility in the longer term. Unsustainable consumption trends are forcing many countries, particularly oil exporters, to rethink their energy pricing and subsidy systems to encourage greater efficiency.

Peak Oil

A vast array of studies have attempted to predict the time at which global oil production will reach a maximum level, from which point it will go into irrevocable decline. Some suggest that this ‘peak’ has already occurred, while others maintain it is either impossible to predict or shows no sign of appearing. Looking further than a decade into the future presents many uncertainties, including: the availability and cost of extraction technologies; substitute technologies; pricing systems in major economies; and carbon legislation. A peak in conventional oil production before 2030 appears likely, and there is a significant risk of a peak before 2020. With average rates of decline from current fields, the report says that just to maintain current production levels would require the equivalent of a new Saudi Arabia coming on-stream every three years. What’s more, giant fields pass peak production levels and there is a shift to smaller, more difficult to produce fields that have faster depletion rates meaning the rate of decline will accelerate. Even before we reach peak oil, we could witness an oil supply crunch because of increased Asian demand.

Unconventional oil, including very heavy oil, oil sands, and tar sands (bitumen), has a high viscosity. It flows very slowly and requires processing or dilution to be extracted through a well bore. Very heavy oil in Venezuela, oil sands in Canada, and oil shale in the US account for more than 80% of unconventional resources.

While some oil companies have invested large amounts in non-conventional oil, there are a number of limiting factors, including: environmental impacts; capital and operating costs; and the energy balance of the whole operation (how much energy is required to extract, process and transport the fuel compared to the final product).

The costs, environmental impact and security implications of these options differ and are at the center of fierce debates about the trade-offs between climate and energy security. For example, CO2 emissions from oil sands are at least 20% higher than for oil currently consumed in the US. This is because the energy input (usually in gas) needed to get the oil out is around three times as much as for conventional oil. It also takes three barrels of water to produce each barrel of oil, most of that being too toxic to return to the rivers. Emissions from shale oil are likely to be higher and those from coal to liquids are at least double the levels of those from conventional oil-based fuel. Gas to liquids would produce emissions some 10% to 15% higher than those from conventional gasoline or diesel.

Over a quarter of US oil production and close to 15% of US natural gas production comes from the Gulf of Mexico. In the summer of 2005, Hurricane Katrina shut off what amounted to around 19% of US refining capacity, damaged 457 pipelines and destroyed 113 platforms. Oil and gas production dropped by more than half; causing a global spike in oil prices. Much of the infrastructure destroyed in 2005 was rebuilt in the same location, leaving it vulnerable to similar weather events in the future.

The US Geological Survey estimates that the Arctic might contain over a fifth of all undiscovered oil and gas reserves. Siberia could contain as much oil as the Middle East. However, dreams of a resource bonanza in the north are premature. The environment is difficult and becoming increasingly unpredictable as a result of the changing climate. The thawing of permafrost in the north is already causing infrastructural damage and reportedly costing Russia around $1.9 billion a year to repair infrastructure and oil and gas pipelines in West Siberia.

Renewable Energy

There are a large variety of sources of renewable energies that are available in different concentrations all over the world. These include:

- Heating and cooling: passive solar architecture; solar thermal collectors; biomass-based combined heat and power; and geothermal energy.
- Electricity: solar photo-voltaic; solar thermal; hydro; solid biomass; biogas; geothermal; on and offshore wind; marine energies like sea current, wave and tidal energies.
- Transport (internal combustion-based): bioethanol; biomethanol; oils from biomass; and biomass-based synthetic fuels.

Until the last decade, the commercial renewable energy field was dominated by hydropower for electricity, biomass for heating, and solar thermal for hot water. However, the commercial strength of onshore wind has led to unprecedented growth in this area in a number of regions. This trend is likely to continue, as will the development of solar power for electricity production. The use of biofuels as a transport fuel remains controversial, due to the impact on food prices, land use and water consumption. If the use of biofuels is to be expanded, it is likely to require rapid technology innovation and the use of non-food sources for fuel, such as algae.

The most common critique of wind and solar power is that they both rely on intermittent sources. This means that thermal or nuclear capacity is still needed as back-up to compensate for times when the wind doesn't blow or the sun doesn't shine.

The growth of the current generation of biofuels is expected to slow due to environmental concerns and the impact of such large-scale production on land use and food prices. These concerns have accelerated the development of the next generation of biofuels, which will no longer use potential food sources for the production of ethanol (such as wheat), but farm waste instead. These could become more widespread in the next couple of years. Commercially viable third-generation biofuels from specially farmed plant forms, such as algae, are still at the research stage.

Water flows are fundamental for agriculture, power generation and cooling. Hydropower contributes around 15% of global electricity production, by far the largest of any renewable energy. It relies on the ability to predict the volume of water entering the system. Before construction, care is taken to assess river levels, hydrological cycles and precipitation patterns. Until recently those findings were considered to be constants. However, climate change is expected to cause accelerated changes in the rainfall patterns and what were constants are now becoming variables. This can cause problems for both glacier-dependent and precipitation-dependent power plants.

Challenges and Risks

In spite of broad international agreement on the importance of inventing and deploying technologies to meet energy and climate security goals, progress has been slow. Uncertainties around domestic and international regulations and pricing structures can stall investment, discourage collaborative projects and generally dampen investor confidence. For example, inconsistent policies have entrenched a pattern of boom and bust in the renewable energy and efficiency industries in many parts of the world, including the US.

Over a quarter of US oil production and close to 15% of US natural gas production comes from the Gulf of Mexico. In the summer of 2005, Hurricane Katrina shut off what amounted to around 19% of US refining capacity, damaged 457 pipelines and destroyed 113 platforms. Oil and gas production dropped by more than half; causing a global spike in oil prices. Much of the infrastructure destroyed in 2005 was rebuilt in the same location, leaving it vulnerable to similar weather events in the future.

All of the world's largest energy importers are dependent on sea imported oil. The US imports 60% of the oil it consumes (over 95% delivered by tankers) while the growing markets of China and India import 90% by sea. Japan is almost completely dependent on maritime oil imports. The traffic is increasing as countries require greater energy imports further from their markets.

Key challenges that will affect businesses across the board are:

- Cost and stability of services
- Pressure to reduce carbon emissions
- The transformative changes in the energy sector
- Price and supply
- Regulatory considerations: counting the cost of carbon
- The food industry could be affected by energy disruption - supermarkets tend to keep only a few days worth of perishables on their shelves
- Environmental risks
- Investment risks
- Technology risks
- Operational risks - Infrastructure and systems *not built* to withstand changing environmental conditions will require expensive retrofitting
- With energy production forecast to grow by approximately 45% over the next two decades, water consumption for energy production will more than double over the same period
- Operating in more difficult terrains increases the risk of accidents which have human, environmental and economic consequences.

Conclusion

Energy security is now inseparable from the transition to a low-carbon economy.

Traditional fossil-fuel resources face serious supply constraints and an oil supply crunch is likely in the short-to-medium term.

Of particular importance for new technologies is the risk of constraints on raw materials such as rare earth metals, as scarcity may drive up costs.

Energy infrastructure will be increasingly vulnerable to unanticipated severe weather leading to a greater frequency of brownouts and supply disruptions.

Increasing energy costs as a result of reduced availability, higher global demand and carbon pricing are best tackled in the short term by changes in practices.

The sooner that businesses reassess global supply chains and just-in-time models, and increase the resilience of their logistics against energy supply disruptions, the better.

While the vast majority of investment in the energy transition will come from the private sector, governments have an important role in delivering policies and measures that create the necessary investment conditions and incentives.

Appendix K

Geothermal Development in Hawaii

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Geothermal resources

The Hawaiian Islands lie above a geological "hot spot" in the earth's mantle that has been volcanically active for the past 70 million years, with the island of Hawaii (Big Island) having the most recent activity. The Big Island has an obvious, large potential for geothermal energy resources, both for electrical generation and direct utilization. Since the 1976 drilling of the HGP-A well and the discovery of the Kapoho Geothermal Reservoir in the lower Kilauea East Rift Zone, geothermal power potential on the Big Island has been estimated at between 500 and 700 Megawatts.

Geothermal interest was 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 was regarded as a renewable source to help make the islands less dependent on imported energy.

The Hawaii Geothermal Resources Assessment Program was initiated in 1978. The preliminary phase of this effort identified 20 Potential Geothermal Resource Areas (PGRAs) using available geological, geochemical and geophysical data.

The second phase of the Assessment Program undertook a series of field studies, utilizing a variety of geothermal exploration techniques, in an effort to confirm the presence of thermal anomalies in the identified PGRAs and, if confirmed, also more completely characterize them.

The island of Oahu, the major population center of Hawaii, is the second oldest major island and was formed from two independent volcanic systems. A preliminary assessment identified six locations where data suggested that a thermal resource might be present. The present assessment of the geothermal potential for Lualualei Valley is that there is a 10 to 20 percent probability of a low-to-moderate temperature resource existing at depths of less than 3 km. The probability of the existence of a moderate-to-high temperature thermal resource within 3 km is less than 5%.

The island of Hawaii, is the youngest and the largest island in the Hawaiian. A number of potential geothermal resources were identified in the preliminary assessment.

- Kilauea East Rift Zone was designated as a Known Geothermal Resource Area due to a productive geothermal well. The probability of a geothermal resource in this area is 100%.
- Kilauea Southwest Rift Zone and has a geothermal resource probability of 100% for a low-to-moderate resource and 70 to 80% for a moderate-to-high resource.
- Mauna Loa area did not exhibit any significant indications of a geothermal resource: less than 5% for a low-temperature resource.
- Kawaihae area is 35 to 45% low-to-moderate resource and less than 15% moderate-to-high.
- Hualalai summit indicated 35 to 45% low-to-moderate resource and 20 to 30% moderate-to-high.

An experimental 3 MW power plant went online in 1982; which, when it was shut down after eight years of production, had an availability factor of 95%. The plant was originally designed as a two-year demonstration project and incorporated several unique characteristics. Because the facility was located in the Kilauea East Rift Zone and therefore, was in a high lava-hazard zone, the turbine-generator set was built on skids, and the building housing the turbine-generator had a bridge crane capable of lifting the turbine-generator unit, so that it could be quickly removed in the event of a lava flow. In addition, the well was housed in a concrete bunker that could be completely enclosed with a set of covers, to allow a lava flow to cover the site without damaging the wellhead. Over the life of the plant, the generator facility produced between 15 and 19 million kilowatt-hours of electricity per year. In 1986 the HGP-A facility was transferred from U.S. Department of Energy ownership to the state of Hawaii and assigned to the Natural Energy Laboratory of Hawaii.

In 1985, the Noi‘i O Puna (Puna Geothermal Research Center) was established to support direct use of the waste heat from the brines of the HGP-A well. The Community Geothermal

Technology Program (CGTP) was conceived in 1986. The purpose of the program was to support small business enterprises in the Puna District, encourage the use of waste heat and byproducts from HGP-A, and to allow access to the geothermal resource.

The HGP-A power plant was closed in late 1989 on the order of Governor John Waihee and County of Hawaii Planning Director Duane Kanuha. The closure of the power plant was permanent due to the fact that it was no longer accomplishing it's primary goal of demonstrating the benefits of geothermal power. Although the facility was designed for only a two-year demonstration life, it has been operated for nearly eight years. During the interval, inadequate maintenance had taken a severe toll on the reliability and effectiveness of the equipment, and the costs of operation exceeded the revenues being generated. In addition, the effluent abatement systems and the brine disposal processes were neither efficient nor acceptable to the community or the regulatory agencies.

Despite the difficulties that were encountered, the facility accomplished a great deal. It demonstrated that the resource in the Kilauea Lower East Rift Zone was robust: the decline in production from the HGP-A well, over the eight year life of the plant, was only a few percent per year. The facility demonstrated that the reservoir fluids required special handling and maintenance, but also demonstrated that fluid chemistry issues could be managed. Some of the techniques for fluid handling and disposal that were developed and tested at the HGP-A facility were employed by the subsequent commercial power plant and proved key to disposal of their waste fluids.

And, finally, the operations, and missteps, taken at the HGP-A facility, served to sensitize Hawaii's regulatory agencies to issues regarding geothermal development that affect the community. It should also be noted that, with the closure of the power generation activities at the HGP-A, the Community Geothermal Technology Program also was terminated due to loss of the waste heat produced by the generation process

Geothermal / Inter-Island Transmission Project

From 1982 through early 1990, an engineering feasibility project was undertaken to evaluate the technical and economic challenges of installing a large-scale 500-megawatt geothermal/inter-island submarine cable. About $26 million (Federal and State funding) was expended in studies, design, engineering, fabrication, and testing for the Hawaii Deep Water Cable Project. The design criteria stated that the cable would have to withstand the stresses of at-sea deployment (including strong currents, large waves, and strong winds), the undersea environment (including corrosion and abrasion), and be able to reliably conduct electricity for thirty years. Since the Alenuihaha Channel is nearly 2,000 meters deep, both deployment (laying of the cables) and operating environment posed exceptional engineering challenges. The rationale for the project was that the primary source of geothermal energy was on the island of Hawaii, and the major electrical load was on the island of Oahu, where Honolulu is located. The scheme under consideration was to use the geothermal energy to generate power and transmit it to Oahu. At the time it was estimated that up to 500 MW could be used on Oahu, whereas only about 100 MW were needed on the Big Island.

The electricity produced by the project could potentially represent a large portion of the electric power supply for Oahu. Thus, the project would have to provide a reliable supply of electricity. The amount of energy that HECO (Hawaiian Electric Company) would purchase would be dependent on HECO's assessment of the reliability of the project and the availability of the electricity.

Puna Geothermal Venture Power Plant

In 1990, the Puna Geothermal Venture Facility, situated on 25 acres of a 500-acre plot, located 21 miles south of Hilo on the Big Island, replaced the HPG-A facility. This facility is in the geologic region known as the Lower East Rift Zone. Puna Geothermal Venture is the first commercial geothermal power plant in the state of Hawaii and currently is capable of producing about 30 MW of power. The power plant comprises 10 combined cycle ORMAT Energy Convertors (OECs) installed in parallel. Each OEC consists of a Level I topping steam turbine and a Level II organic turbine connected to a common generator.

Puna Geothermal Venture provides nearly a quarter of the power consumed on the Island of Hawaii. That is enough electricity to meet the needs of more than 25,000 residents and visitors. As of April 2002, the power plant has produced a total of 1.9 billion kWh, and displaced a total of 552 tons of oil.

In 2000, Puna Geothermal Venture announced its intention of doubling its electrical generation capacity from 30 MW to 60 MW. The wells supply geothermal steam at high pressure which must be reduced with valves before the steam goes through the generators. Puna Geothermal Venture plans to place an 8 MW generator at the well to reduce pressure to the other generators while producing power. In the long run, the company can increase capacity to 50 MW without any new wells.

In 2001, Puna Geothermal Venture was chosen to operate the Puna Geothermal Research Center (Noi‘i O Puna) facility by the Natural Energy Laboratory of Hawaii Authority. Puna Geothermal Venture proposed continued power production while also developing new production capabilities without drilling new wells. They plan to solicit proposals from entrepreneurs and sell them thermal energy. PGV will refurbish and expand the visitor center and will also make reasonable efforts to solicit proposals from the public for the development, construction, operation and maintenance of a geothermal heat source on the property. PGV will market facilities to transfer surplus heat from their geothermal facility and within the Noiʻi O Puna facility for geothermal related businesses of local entrepreneurs.

Regulation Impediments

The regulatory regime seems to be quite complex. There is the Geothermal Resource Subzone (GRS) Assessment and Designation Law (Act 296, SLH 1983), the Hawaii County Planning Commission's Rule 12, and Act 301, SLH 1988 just to name a few.

The Geothermal Resource Subzone Law stated that the exploration and development of Hawaii's geothermal resources are of statewide benefit and this interest must be balanced with preserving Hawaii's unique social and natural environment.

Three Geothermal Resource Subzones were designated by the Board of Land and Natural Resources after evaluating a number of factors including social and environmental impacts. The subzones total 22,300 acres in the middle and lower Kilauea Rift Zone and 4,000 acres in the Haleakala Southwest Rift Zone.

Public-Acceptance Hurdles

The development of geothermal energy in the Kilauea East Rift Zone has stirred a significant amount of controversy. The experimental HGP-A power plant was not perceived as a "good neighbor" due to emission releases, the extent of brine ponds beyond the plant boundaries, and an unkempt appearance of the plant itself because of limited maintenance. Further exploration was opposed, often vehemently, by people expressing concern over various issues, including impacts on Hawaiian cultural and religious values, potential geologic hazards, public health, and loss of native rainforest, as well as changing the rural nature of Puna. During the establishment of the Puna Geothermal Venture plant, an episode of planned open venting and a number of uncontrolled steam releases stimulated the evacuation of some nearby residents and enhanced fears that the resource could not be safely tapped.

Since the PGV plant has been operating for a decade, most Hawaii residents have accepted it as part of the power supply. However, there is continued concern about health and environmental issues among some residents near the plant which have resulted in investigations by the US Environmental Protection Agency and a program documenting residents' health problems, which they attribute to geothermal emissions. The relationship between PGV and its neighbors appears to have improved with better communication between the company and the adjacent residents.

Among the issues which have concerned geothermal opponents are:

- 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

Opposition Issues

According to state regulations, the exploration and development of geothermal resources can be permitted within conservation, agricultural, rural, and urban areas. The vast majority of resources are located in predominantly rural areas and in some cases, geothermal resources may be present in more primitive tracts where direct human impacts or occupation are minimal such as the Wao Kele O Puna rainforest. In the former case, many of the residents of these rural areas moved there to escape urbanization and industrialization of more populous counties of states (e.g., Honolulu, California), and the implementation of an industrial activity–the generation of geothermal power–was completely contrary to their lifestyle. In the latter situation, the installation of power production facilities in the rainforest–even one degraded by invasive exotic/non-native plants and animals–was equally offensive to other interest groups in the state.

An uncontrolled venting incident in June 1991 at the Puna Geothermal Venture project on the Big Island released hydrogen sulfide and other gases, and gave ample validation to the concerns of the area residents regarding the adverse impacts of this development on their communities. As a result of the “blowout,” a Geothermal Management Plan was developed that has enabled state and county agencies to better regulate geothermal activity and enforce permit conditions.

Nonetheless, geothermal wells are sometimes vented intentionally for a few hours to clear the well and pipelines resulting in a temporary release of steam and abated gases. These events can be noisy for a short time and, in addition, the power plant equipment (e.g., cooling tower fans, pumps, etc.) do emit continuous low-level noise during normal power plant operations. Hence, some impact on the community from power production is inescapable; it serves as a continuous irritation to those who feel that their environment has been invaded by industrialization.

A more intangible objection was also raised by some native Hawaiians who claimed that the development of geothermal power was interfering with their worship of Pele, the Goddess of volcanoes. These objections were taken as far as the U.S. Supreme Court, who found that geothermal development does not interfere with religious freedom.

The disputes over the development of a geothermal industry in Hawaii culminated in several actions by the state and the geothermal opponents that effectively ended any serious effort to develop any significant geothermal production capacity on the island of Hawaii, or in the state at all.

In 1991, there were two entities actively pursuing development of the geothermal resource on the Kilauea East Rift Zone: Puna Geothermal Venture on the lower rift, and True Geothermal Energy Company in the middle rift area. The former was in the process of constructing their power plant and proving up their resource; whereas, the latter, having spent about 10 years struggling with the regulatory environment, was in the process of drilling the first of their exploration wells. When Puna Geothermal Venture lost control of one of their wells during drilling and allowed the uncontrolled release of steam from their exploration well, the state regulatory agencies suspended–indefinitely–the geothermal drilling permits of both Puna Geothermal Venture as well as the True Geothermal Energy Company. The latter company interpreted the loss of their permits–even though they were in compliance with their permit conditions–as an indication of waning political support for geothermal development by the state political powers. This loss of support, as well as less than hoped-for success in their exploratory drilling, ultimately led to their abandonment of further efforts to develop their project on the middle rift subzone.

The second event that further eroded momentum for the geothermal program resulted from an effort by the state to obtain additional federal support for the combined geothermal/inter-island cable program. In this effort, the state presented all of the state- and federally-sponsored research, development, and demonstration activities up to that date as a single unified program designed to lay the foundation for large-scale, 500-megawatt-development of Hawaii's geothermal resources. Although this strategy was intended to rationalize significant, additional federal investment in the RD&D effort, it had unexpected and adverse consequences.

Soon after the state presented the program as a unified effort, the Sierra Club Legal Defense Fund brought suit against the state and the U.S. Department of Energy in an effort to force the relevant agencies to conduct a Federal Environmental Impact Statement on the full 500-MWe development. The U.S. DOE expended -$5 million in an effort to conduct an EIS, but made minimal progress in meeting the demands of the geothermal opponents. Ultimately, the state and DOE settled with the plaintiffs in the suit by signing a "consent decree" that effectively barred the Hawaii governor–for the duration of his term in office–from providing support to any program that would further the state's objective of developing large-scale geothermal power production or transmission inter-island. The state's capitulation to the demands of the opponents, as well as a declining real cost of petroleum for electrical power production, effectively ended any serious effort to develop geothermal power generation beyond that of the Puna Geothermal Venture efforts on the lower east rift zone.

Nearly a decade has passed since many of these events occurred. Puna Geothermal Venture was, however, able to bring a 35-megawatt power plant online–after many delays and much greater costs than had been anticipated by their original investors. Although technical challenges remain a significant concern in the operation of this facility, it has managed to produce power with a minimum of steam releases into the community and a minimum of public controversy.

And the company has been able to obtain permits to expand their production to 60 MWe. However, there are no current plans to expand their production capacity, and there is little serious discussion given to significant expansion of geothermal capacity either on the island of Hawaii or elsewhere in the state. Undoubtedly, this situation is the result of the currently low cost of petroleum–in "real" dollars–but is also in recognition of the severe regulatory and political risks any new investment in significant geothermal production capacity would face in Hawaii today.

Renewable Portfolio Standard

A Renewable Portfolio Standard (RPS) is a policy to encourage the use of renewable energy sources. It sets minimum targets for the production of electricity generated from renewable resources. The aim is to ensure deployment of renewable energy to enjoy the benefits of reduced energy costs, reduced exposure to the economic effects of volatile oil markets, risk management by diversifying generation options, job creation and economic benefits, and environmental benefits.

The state of Hawaii has an extremely high dependence on imported fuels for energy; 90% of the energy supplies are imported oil and coal. Therefore, increased use of renewable energy would achieve increased energy security, reduce some of the environmental risks associated with fuel transport, and reduce the flow of money out of the state. The cost of electricity in Hawaii is the highest of any state in the United States with average price per kWh in September 2000 of $0.144 -- that's over twice the U.S. average price per kWh of $0.0691.

Not only were Hawaii's electricity prices per kWh the highest in the nation in October 2000, electricity revenues per kWh for Hawaii utilities grew much faster than the U.S. average over the years since 1990. Hawaii's revenues per kWh were 59.6% higher than the average for 1990 while the U.S. average was only 3.3% higher. For comparison, Honolulu consumer prices increased about 25.5% from 1990 to 1999.

Electric utilities in Hawaii are “regulated monopolies” meaning they are allowed to operate without competition, but must follow rules set by the Public Utilities Commission. By adopting a renewable portfolio standard, the use of renewable energy becomes one of those rules.

Hawaii’s dependence on fossil fuels is expected to grow over the coming decade unless action is taken to increase the use of renewable energy. In 1999, Hawaii's four electric utilities sold 9,373.8 Gigawatt hours (GWh) of electricity. Statewide, utilities forecast that electricity sales will grow at an average annual rate of 1.6% during the 1999 through 2010 period, reaching approximately 11,192 GWh in 2010.

In 1999, renewable energy (geothermal, municipal solid waste, bagasse, landfill methane gas, hydro and wind) was used to produce 7.2% of the electricity generated for sale by the four electric utilities. Renewable energy generation capacity was reduced in 2000 by the closure of Lihue Plantation on Kauai and Pioneer and Paia Mills on Maui. If the remaining renewable energy resources in operation at the end of 2000 continue in operation through 2010, they will provide an estimated 642 GWh of sales during each year of the period. This will amount to approximately 6.6% of total electricity sales in 2001. As electricity demand grows, the percentage of electricity sales from renewable resources will decline to approximately 5.7% statewide by 2010.

Hawaii has an abundance of renewable energy resources. Several studies have shown that at least 10.5% of Hawaii’s electricity could be generated from renewable resources by 2010 with no increase in cost to Hawaii’s residents.

Increased use of renewable energy sources through the implementation of a RPS can result in many benefits to Hawaii including:

- Reduced cost of fuel for electricity generation
- Reduced reliance on imported oil supplies and exposure to oil market prices
- Risk management by diversifying the portfolio of electricity generation options
- Job creation and economic benefits
- Environmental benefits

Conclusion

There is still resistance to using geothermal energy by some members of the local community, even though the issues noted above have been -- and continue to be -- addressed by government and PGV. However, there are well organized groups (such as the Pele Defense Fund, Rain Forest Action Network and other community organizations) that continue to express concern about the abilities of government and developers to provide socially and environmentally sound geothermal power. Furthermore, the level of support given by the state's political establishment to expansion of geothermal capacity remains vanishingly small. There is presently only funding for one geothermal staff person at the state level.

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