A Catalog of Potential Sites for Renewable Energy in Hawaii

WIND

SOLAR THERMAL

PHOTOVOLTAIC

BIOMASS

BIOFUELS

BIOGAS

GEOTHERMAL

HYDROELECTRICITY

OCEAN WAVE

OCEAN THERMAL ENERGY CONVERSION

A Catalog of Potential Sites for Renewable Energy in Hawaii

December 2006

Produced for the State of Hawaii Department of Land and Natural Resources
and the Department of Business, Economic Development, and Tourism

by Global Energy Concepts, LLC

in response to Act 95, Session Laws of Hawaii 2004

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1. Introduction

Purpose

This Catalog documents extensive information available to identify the numerous opportunities to develop Hawaii's abundant renewable energy resources. The Catalog was produced in response to a provision of Act 95, Session Laws of Hawaii (SLH) 2004, which established a Renewable Portfolio Standard. This provision was codified as §196-41, Hawaii Revised Statutes (HRS), state support for achieving renewable portfolio standards, which, among other things, required the Department of Land and Natural Resources (DLNR) and the Department of Business, Economic Development, and Tourism (DBEDT) to facilitate the private sector's development of renewable energy projects by supporting the private sector's attainment of the renewable portfolio standards. Both departments were charged with providing meaningful support in areas relevant to the mission and functions of each as provided in this section, as well as in other areas the department Directors may deem appropriate.

§196-41,HRS specifically tasked DLNR to produce and publish this Catalog of potential sites for the development of renewable energy by December 31, 2006, with updates every five years thereafter. DBEDT assisted in this project by providing funds for a consultant and project management based upon its policy and technical expertise in renewable energy.

The following renewable energy technologies are considered:

- Wind energy
- Solar thermal
- Photovoltaic
- Biomass, biofuels, and biogas (produced from dedicated energy crops, agriculture and food processing waste, municipal solid waste, landfill gas, and other sources)
- Geothermal
- Hydroelectricity
- Ocean energy (including wave energy, energy from ocean currents, and ocean thermal energy conversion)

Drawing from several public studies and GIS data layers, the Catalog brings together state-wide listings of prospective sites and information on the major resources into a single comprehensive publication. It does not provide a new assessment of Hawaii's energy resources, but rather documents the current understanding of these valuable opportunities and summarizes the considerations affecting development.

While the listings of potential sites contained in this Catalog have been drawn from substantial research, the contents do not eliminate the need for further site evaluation activities. However, they can help developers focus on the most promising areas and significantly minimize the cost and time involved in prospecting and pre-development work.

DLNR and DBEDT believe the contents of the Catalog to be accurate but do not guarantee the accuracy or completeness of the information included in this Catalog and assume no liability for the use of the information.

A Geographic Overview of Hawaii

Hawaii is over 2,400 miles away from the mainland United States, the nearest continental landmass, making Hawaii one of the world's most remote groups of islands. Described by Mark Twain as "the loveliest fleet of islands that lies anchored in any ocean," there are eight major Hawaiian Islands: Kauai, Oahu, Lanai, Molokai, Maui, Niihau, Kahoolawe, and Hawaii (often referred to as the "Big Island of Hawaii").

Figure 1 shows Hawaii's major islands and their relationship to each other in terms of size and location. It also shows the service territories of Hawaii's four electric utilities. The Hawaiian Electric Company, or HECO, serves the Island of Oahu. HECO has two subsidiaries, Hawaii Electric Light Company (HELCO) serving the Island of Hawaii, and Maui Electric Company (MECO), serving the three islands of Maui, Molokai, and Lanai with three independent systems. Kauai is served by the Kauai Island Utility Cooperative.

All Hawaii electric utilities are regulated by the Hawaii Public Utilities Commission (PUC). Independent power producers can sell power only to the utilities.

Unlike utilities on the mainland United States, Hawaii utilities cannot turn to neighboring states to make up for any temporary or long-term energy shortages. Hawaii's electric utilities cannot even turn to the utility serving the next county for electricity in the event of problems. The Hawaiian Islands also have no indigenous fossil fuel resources.

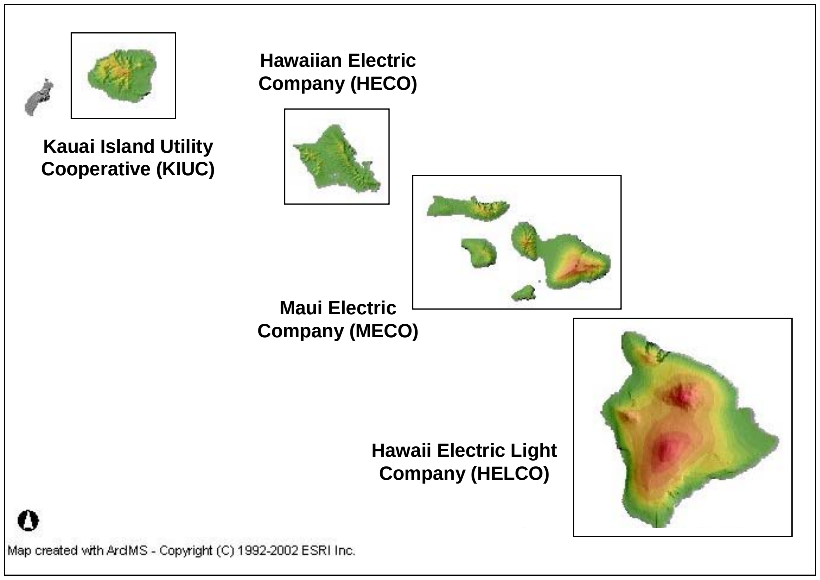

Figure 1. Hawaii's Major Islands and Utility Service Territories

Organization of the Catalog

The Catalog begins in Section 2 with an overview of Hawaii's need for renewable energy, state energy objectives, and its renewable portfolio standard. Section 2 also discusses Hawaii's electric utilities, the high cost of electricity and utility fuel, and the electricity supply mix. Section 3 introduces a useful tool for obtaining information relevant to siting projects: Hawaii's interactive Geographic Information System (GIS) free data layer download site.

The next section, Section 4, summarizes assessments of available renewable energy resources and provides an overview of these resources by Island. It also summarizes important considerations in developing renewable energy projects including zoning, transmission constraints, electricity demand profiles, land use, and environmental concerns.

Section 5 provides details on each of the six major renewable energy technologies. For each technology, information is provided on installed and planned projects, development areas, land ownership and uses, and other information.

The final section, Section 6, provides contacts and additional resources.

2. Background

Hawaii's Need for Renewable Energy

Hawaii needs renewable energy to reduce the cost of energy to its citizens, avoid the negative economic effects of volatile oil prices, reduce its overdependence on oil, and increase its energy security by reducing imports from overseas. Renewable energy can grow new industries in Hawaii, provide jobs and income for its citizens, and protect its environment, which is also the basis of its economy.

Hawaii's citizens pay the nation's highest energy costs. This is in part due to the fact that Hawaii is the most oil-dependent of the 50 states. In 2005, Hawaii relied on imported fossil fuels (petroleum and coal) for 94.5% of its primary energy needs, at a cost of $4.62 billion. The Hawaiian Islands have no fossil fuel resources and do not import natural gas.

Since most of Hawaii's oil is from foreign countries, this dependence raises energy security concerns. Only about 13% of Hawaii's oil imports came from U.S. sources in 2005. In recent years, increasing percentages of Hawaii's oil imports have come from the Middle East, reaching almost 23% in 2005. Hawaii's coal comes from Australia and Indonesia.

In the electricity sector, oil was used to produce 80% of electricity sold by Hawaii's electric utilities in 2005. The remaining electricity generation was supplied by coal (13.9%), MSW (2.6%), geothermal (2%), hydroelectricity (0.7%), bagasse (sugarcane waste) (0.6%), wind (0.1%), and a very small amount from photovoltaic.

State Energy Objectives

Given its dependence on oil imports, the State has established the following energy objectives in §226-18, Hawaii Revised Statutes (HRS), Objectives and policies for facility systems—energy, which reads as follows:

"(a) Planning for the State's facility systems with regard to energy shall be directed toward the achievement of the following objectives, giving due consideration to all:

> (1) Dependable, efficient, and economical statewide energy systems capable of supporting the needs of the people;
>
> (2) Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased;
>
> (3) Greater energy security in the face of threats to Hawaii's energy supplies and systems; and
>
> (4) Reduction, avoidance, or sequestration of greenhouse gas emissions from energy supply and use.

(b) To achieve the energy objectives, it shall be the policy of this State to ensure the provision of adequate, reasonably priced, and dependable energy services to accommodate demand."

Consistent with these objectives, Hawaii's top energy priorities are increasing renewable energy use and energy efficiency.

Hawaii has taken many steps to encourage renewable energy development. In addition to its abundant and diverse renewable resources, Hawaii features solid technological infrastructure and economic incentives to attract new energy investments and business opportunities. Hawaii's islands beckon renewable energy developers with an attractive business environment, a strong policy context, valuable map data, significant pre-development investigation into viable development locations, and potential tax credits.

The Hawaii State Department of Business, Economic Development, and Tourism's (DBEDT) Strategic Industries Division (SID) is the state's energy office, and the Director of DBEDT is the state's Energy Resources Coordinator. Under the Director's leadership, SID promotes commercialization of Hawaii's sustainable energy resources and technologies to reduce the state's high dependence on imported oil, increase local economic development, and reduce the potential negative economic impacts of oil price fluctuations. DBEDT's activities include providing resource data; technical and economic analyses; support for research, demonstration, development, and application of renewable energy technologies; partnerships and technology transfer; and public outreach.

The Hawaii Department of Land and Natural Resources (DLNR) is tasked with managing all of the natural and cultural resources within the state's public lands and ocean waters.

Hawaii's has adopted a broad range of policies supporting the development of renewable energy technologies. By fostering demand and providing financial incentives, these policies can play a significant role in building the renewable energy marketplace.

Renewable Portfolio Standard

A principal policy to support increased renewable energy use and energy efficiency is Hawaii's Renewable Portfolio Standard (RPS), initially set as a goal in 2001. It was upgraded to a mandate in 2004 and further refined in 2006 by Act 162, Session Laws of Hawaii (SLH) 2006. The RPS is codified in §269-91 to 95, and 196-41, HRS. As amended in 2006, §269-92 (a) requires that:

"Each electric utility company that sells electricity for consumption in the State shall establish a renewable portfolio standard of:

(1) Ten per cent of its net electricity sales by December 31, 2010;

(2) Fifteen per cent of its net electricity sales by December 31, 2015; and

(3) Twenty per cent of its net electricity sales by December 31, 2020."

The initial goal and Act 95, SLH 2004, had set standards of 7% by 2003, and 8% by 2005, which were attained by the utilities. Since these were historical milestones and had been achieved when additional modifications were made to the RPS in 2006, the 2003 and 2005 targets were amended out of the statute by Act 162, SLH 2006.

In the Hawaii context, "each electric utility" applies to two entities: the Hawaiian Electric Company combined with its affiliates, Maui Electric Company and the Hawaii Electric Light Company; and the Kauai Island Utility Cooperative. While KIUC attained 8.1% renewable energy electricity generation in 2005, the HECO companies only attained 6%, but met the standard by including energy efficiency and electricity offsets, such as solar water heating, as provided for by the definition of "renewable electrical energy", below. The HECO companies will gain a major boost from a total of 60 MW of new wind, all of which will be on line in 2007.

In the 2006 Legislative Session, §269-91, HRS, was amended by Act 162, SLH 2006, which added two new definitions related to the RPS. These included:

"'Biofuels' means liquid or gaseous fuels produced from organic sources such as biomass crops, agricultural residues and oil crops, such as palm oil, canola oil, soybean oil, waste cooking oil, grease, and food wastes, animal residues and wastes, and sewage and landfill wastes.

‘Renewable electrical energy’ means:

(1) Electrical energy generated using renewable energy as the source;

(2) Electrical energy savings brought about by the use of renewable displacement or off-set technologies, including solar water heating, seawater air-conditioning district cooling systems, solar air-conditioning, and customer-sited, grid-connected renewable energy systems; or

(3) Electrical energy savings brought about by the use of energy efficiency technologies, including heat pump water heating, ice storage, ratepayer-funded energy efficiency programs, and use of rejected heat from co-generation and combined heat and power systems, excluding fossil-fueled qualifying facilities that sell electricity to electric utility companies and central station power projects.”

In addition, Act 162, SLH 2006 revised the definition of “Renewable portfolio standard” as “the percentage of electrical energy sales that is represented by renewable electrical energy.”

The definition of “renewable electrical energy” coupled with the revised RPS definition means that energy efficiency and energy off-set technologies also count toward the RPS standard. However, this Catalog focuses on the technologies listed in the amended definition of renewable energy inserted by Act 162, with the exception of hydrogen as a potential product created by electrolysis using electricity from a renewable energy technology. The definition of renewable energy per Act 162 reads as follows:

“‘Renewable energy’ means energy generated or produced utilizing the following sources:

(1) Wind;

(2) The sun;

(3) Falling water;

(4) Biogas, including landfill and sewage-based digester gas;

(5) Geothermal;

(6) Ocean water, currents and waves;

(7) Biomass, including biomass crops, agricultural and animal residues and wastes, and municipal solid waste;

(8) Biofuels; and

(9) Hydrogen produced from renewable energy sources.”

It should also be noted that Hawaii’s RPS carries the intent of expanded use of renewable energy beyond 20% and beyond 2020. It requires the state’s Public Utility Commission (PUC) to contract with the University of Hawaii’s Hawaii Natural Energy Institute to conduct a peer-reviewed study every five years to develop a recommendation as to whether to revise the RPS. It empowers the PUC to review and revise the RPS every five years, with neither 20%, nor the year 2020 as limits.

Electric Utilities

Hawaiian Electric Company

The Hawaiian Electric Company (HECO) along with its subsidiaries, Maui Electric Company (MECO) and Hawaii Electric Light Company (HELCO), provide electricity to Oahu, Maui, the Island of Hawaii, Lanai, and Molokai. Renewable energy resources provide a growing portion of HECO’s generation mix and the companies have signed a number of power purchase contracts for renewable energy projects. Some of these projects are currently operating; others are in development. However, as of 2005, almost 79.2% of electricity sold by the utilities on these islands was generated using oil.

While HECO owns two other utilities, each island grid is independent and is not connected with any other grid. Due to the depths of the channels between the islands, both the difficulty of laying cables and the operating environment pose major engineering challenges to inter-island submarine cable designs proposed in the past. The individual utility systems generally experience relatively low loads, especially at night. Further, available transmission capacity and loading on each individual island can affect the feasibility of renewable energy development at certain sites.

In 2002, HECO formed an unregulated renewable energy subsidiary, Renewable Hawaii, Inc., to invest in renewable energy generation projects for Hawaii. In 2003 and 2004, Renewable Hawaii released a series of Requests for Proposals (RFPs) for renewable energy projects on (1) Oahu; (2) Maui, Molokai, and Lanai; and (3) the Island of Hawaii, in that order. Renewable Hawaii received numerous proposals and pursued discussion with six developers of renewable projects, including wind, solid waste, and landfill gas resources. Renewable Hawaii issued a second round of RFPs in 2005. Although none of these projects have been built, Renewable Hawaii is an example of HECO's efforts to acquire renewable energy.

Kauai Island Utility Cooperative

The island of Kauai is served by the Kauai Island Utility Cooperative (KIUC). Oil accounted for 89.6% of KIUC's fuel mix in 2005. KIUC recently released RFPs for renewable energy generation and the company has negotiated several power purchase contracts with renewable energy project developers. While these projects have not yet been built, they are indicative of KIUC's desire for renewable energy on Kauai. Additional information on these projects is included in later sections of the Catalog.

Reducing Hawaii's High Electricity Costs

Hawaii ratepayers pay the highest statewide average electricity rates in the United States. Table 1 shows the amounts paid by customer rate class in September 2006. While HECO has some additional rate classes, the table shows the most important rate classes and those generally common to other utilities. The lack of economies of scale and the expense of fossil fuels, especially oil, help drive the Hawaii electricity prices upward.

Avoided cost has historically been the basis of utility payments to independent power producers. Table 2 shows HECO and KIUC third quarter 2006 avoided costs. The amount comprises fuel cost per kWh and a nominal operations and maintenance cost. One concern of the State of Hawaii's Administration and Legislature was that the price of renewable energy under power purchase contracts would be effectively linked to the price of oil and would continue to escalate rapidly along with oil prices.

As a result of this concern, in 2006, the Legislature passed Act 162, SLH 2006, which amended §269-27.2, HRS, Hawaii Revised Statutes, and changed subsection (c) to read as follows:

> "(c) The rate payable by the public utility to the producer for the non-fossil fuel generated electricity supplied to the public utility shall be as agreed between the public utility and the supplier and as approved by the public utilities commission; provided that in the event the public utility and the supplier fail to reach an agreement for a rate, the rate shall be as prescribed by the public utilities commission according to the powers and procedures provided in this chapter.
>
> In the exercise of its authority to determine the just and reasonable rate for the non-fossil fuel generated electricity supplied to the public utility by the producer, the commission shall establish that the rate for purchase of electricity by a public utility shall not be more than one hundred per cent of the cost avoided by the utility when the utility purchases the electrical energy rather than producing the electrical energy.
>
> The commission's determination of the just and reasonable rate shall be accomplished by establishing a methodology that removes or significantly reduces any linkage between the price

of fossil fuels and the rate for the nonfossil fuel generated electricity to potentially enable utility customers to share in the benefits of fuel cost savings resulting from the use of non-fossil fuel generated electricity. As the commission deems appropriate, the just and reasonable rate for non-fossil fuel generated electricity supplied to the public utility by the producer may include mechanisms for reasonable and appropriate incremental adjustments, such as adjustments linked to consumer price indices for inflation or other acceptable adjustment mechanisms."

This new rate methodology should create a win-win situation both for renewable energy developers and electricity ratepayers of Hawaii.

Table 1. Selected Hawaii Electric Utility Rates, September 2006 ($/kWh)

Rate Schedule	HECO Class	HECO Rates	HELCO Rates	MECO Rates	MECO Lanai Rates	MECO Molokai Rates	KIUC Class	KIUC Rates
Residential	R	$0.1975	$0.3109	$0.2805	$0.3248	$0.3450	D	$0.3402
General Service Non-Demand		$0.1930	$0.3333	$0.2913	$0.3419	$0.4039	G	$0.3575
General Service Demand		$0.1681	$0.2843	$0.2697	$0.3438	$0.3611	J *	$0.3266
Cooking, Heating, AC, Refrigeration	H	$0.0957	$0.2789	$0.2652	$0.3176	$0.3056		
Large Power Secondary Voltage	PS	$0.1533					P	$0.3191
Large Power Primary Voltage	PP */P **	$0.1514	$0.2720	$0.2555	$0.3260	$0.3285	L	$0.3099
Public Street Lighting	F	$0.2124	$0.2273	$0.2905	$0.3469	$0.3657	SL	$0.2339
Time-of-Use Service	U	$0.1598	$0.2843	$0.2697	$0.3478	$0.3611		

Sources: Utility Effective Rate Sheets for September 2006

Notes: * High rate of range shown. ** Rate class designation for HELCO and MECO

Table 2. Hawaii Electric Utility Avoided Cost, Third Quarter 2006 ($/kWh)

HECO	HELCO	MECO	MECO Lanai	MECO Molokai	KIUC
$ 0.1342	$0.1982	$0.2032	$0.2168	$0.2158	$0.1819

Sources: Avoided Energy Cost filings with Public Utilities Commission by HECO Companies

KIUC Effective Rate Sheets for September 2006

3. GIS Tools and Data Layers Available

Hawaii's government leaders recognize that finding prime locations for renewable energy projects depends on many factors such as the location and amount of the resource, the location of transmission lines and substations, identification of protected areas (e.g., wetlands, forest, and marine sanctuary), vegetation and terrain characteristics, and proximity to areas designated for tourism or recreation. The State of Hawaii has a wealth of data available in its Geographic Information System (GIS), a tool to assist analyses of the spatial relationships between land/water resources and activities.

Hawaii's GIS resources consist of substantial computer hardware and software that inventory, analyze, manage, and display a wide variety of location-based information that can be used to support decision making for planning and management of land use, natural resources and the environment, transportation, facilities and services, public administration, and research. The State's GIS data layers allow for visual review of geographically referenced data that traditional charts, graphs, and spreadsheets cannot provide. Hawaii's interactive mapping tools allow users to ask where, why, and how various geographical attributes interact as well as to view relationships, patterns, and trends that might not otherwise be seen.

Developers looking to site renewable energy projects in Hawaii can use the State's GIS tools to view the location of population centers, transmission lines, conservation lands, protected waters, and the resource itself, such as agricultural areas suitable for bioenergy crops, transfer stations for municipal solid waste, or solar insolation potential. This type of information can be viewed by accessing the tabular, spatially referenced data files that create the mapping layers.

The State of Hawaii has made many of these map data layers available free of charge to the public. A Hawaii Ad Hoc State GIS Task Force was created in the late 1980s to examine the use and implementation of a GIS system for state agency planning as well as for public use. The Hawaii State Office of Planning is now responsible for coordinating and maintaining the GIS information obtained or created by various state agencies. Users can either download map data layers or interactively view selected layers using the Office of Planning's web-based application, "I-Map Hawaii." The Office of Planning has also prepared several maps available for download as images. All of these features can be accessed through the portal to the Office of Planning's GIS website, www.hawaii.gov/dbedt/gis/index.html.

Nearly 150 individual spatially referenced data sets are available at this website, organized into physical features/base-map layers, political boundaries/administrative layers, natural resource/environmental layers, hazard layers, and coastal/marine layers. Figure 2, showing transmission lines and population density on Oahu, is an example of the type of map that can be created from data downloaded from the Office of Planning's website. A developer could use this map to identify locations that are near transmission lines but away from population centers to minimize visual impacts.

Free programs, such as Google Earth (http://earth.google.com), and Arc Explorer (www.esri.com/software/arcexplorer/), allow users to manipulate the downloaded data layers; more complex data analysis can be conducted with commercial software. The Office of Planning's website includes a page of links to several other sources of GIS data: http://www.hawaii.gov/dbedt/gis/links.htm.

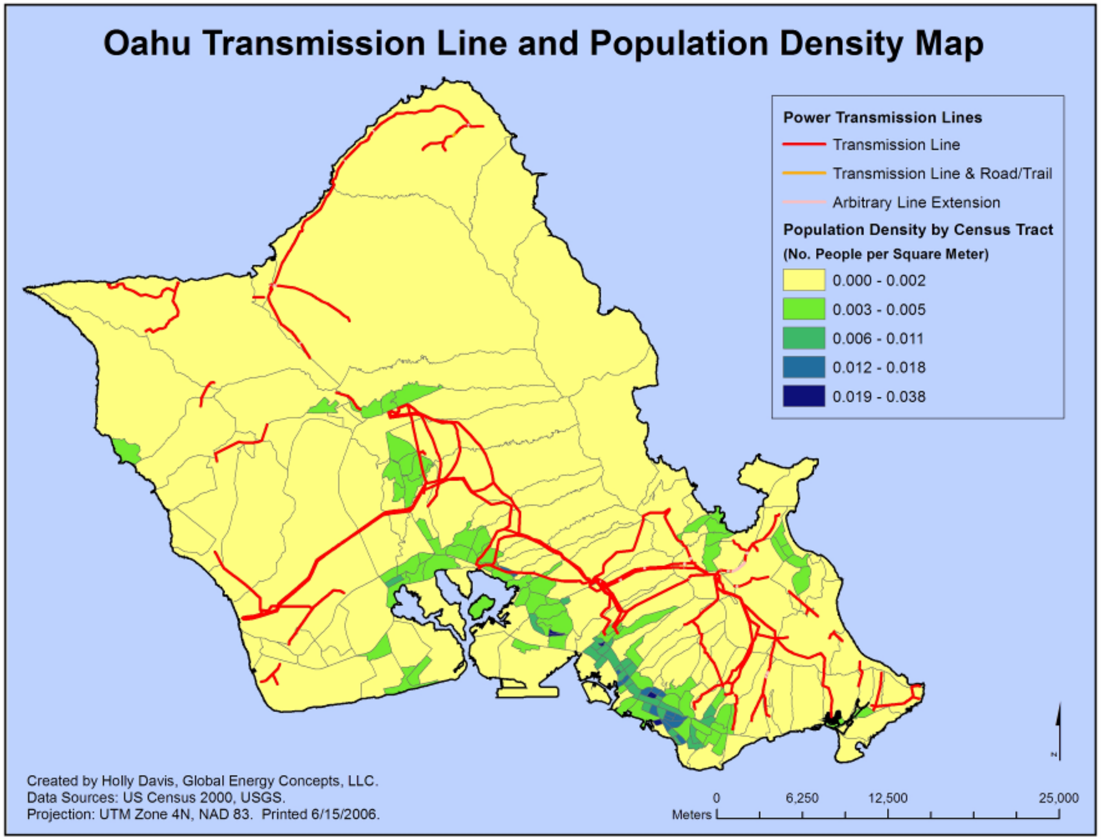

Figure 2. Oahu Transmission and Population Density
(NOTE: Transmission line data is incomplete)

I-Map Hawaii

The I-Map Hawaii web-based GIS viewer allows users to choose from more than 80 layers of geographic data, accessible at www.hawaii.gov/dbedt/gis/i-map.htm. Table 3 shows which I-Map layers might useful for particular renewable energy technologies. A layer is considered potentially useful for renewable energy development if it contains resource data for a particular technology, general information (e.g., population), and land uses, or is a base-map layer such as roads.

Table 3. I-Map Hawaii Layers Useful for Renewable Energy Development

Layer	Wind	Solar	Biomass	Geo	Hydro	Ocean
100- & 500-Year Flood Zones	✓	✓	✓	✓	✓	✓
2000 Census Designated Places	✓	✓	✓	✓	✓	✓
2000 Census Hawaiian Homelands	✓	✓	✓	✓	✓	✓
2000 County Census Division	✓	✓	✓	✓	✓	✓
2000 State Land Use District Boundaries	✓	✓	✓	✓	✓	✓
3-mile Nautical Boundary						✓
600-ft Bathymetric Contour						✓
Agricultural Land use (ALUM)	✓	✓	✓	✓	✓	
Agricultural Productivity Ratings	✓	✓	✓	✓	✓	
Aids to Navigation						✓
Aquifers			✓		✓	
Boating Facilities						✓
Body Surfing Sites						✓
Bottom Type						✓
Coastline	✓	✓	✓	✓	✓	✓
Coral Reefs						✓
Detailed Vegetation – Hawaii	✓	✓	✓	✓	✓	
Development Plan Boundaries	✓	✓	✓	✓	✓	✓

Layer	Wind	Solar	Biomass	Geo	Hydro	Ocean
Dumping Areas	✓	✓	✓	✓	✓	✓
Elevation Ranges	✓	✓	✓	✓	✓	
Enterprise Zones	✓	✓	✓	✓	✓	✓
Explosive Dumping Areas						✓
Fish Aggregating Devices						✓
Fish Havens						✓
Fishponds					✓	✓
Generalized Vegetation	✓	✓	✓	✓	✓	
Government Land Ownership	✓	✓	✓	✓	✓	
Harbors						✓
Hillshades	✓	✓	✓	✓	✓	
Historic Land Divisions – Oahu	✓	✓	✓	✓	✓	
Historical Tsunami Wave Heights						✓
Hunting Areas	✓	✓	✓	✓	✓	
Hydrographic Units			✓		✓	
Hydrography			✓		✓	
Important Agricultural Lands (ALISH & LESA)	✓	✓	✓	✓	✓	
Land Satellite	✓	✓	✓	✓	✓	✓

Table 3. I-Map Hawaii Layers Useful for Renewable Energy Development

Layer	Wind	Solar	Biomass	Geo	Hydro	Ocean
Land Use/Land Cover	✓	✓	✓	✓	✓	
Main Hawaiian Islands	✓	✓	✓	✓	✓	✓
Major Roads	✓	✓	✓	✓	✓	✓
Marine Managed Areas						✓
Median Annual Rainfall (mm)			✓		✓	
Na Ala Hele Trails	✓	✓		✓	✓	
Natl Marine Humpback Whale Sanctuaries						✓
Ocean Recreation Areas						✓
Ocean Recreation Sub-Zones						✓
Offshore Obstructions						✓
Overlapping Ocean Recreation Zones						✓
Parks	✓	✓	✓	✓	✓	✓
Perennial Streams			✓		✓	
Place Names	✓	✓	✓	✓	✓	✓
Public Schools		✓				
Reserves	✓	✓	✓	✓	✓	
Sewer Outfalls (Oahu, Maui, Hawaii)						✓
Solar Radiation		✓				

Layer	Wind	Solar	Biomass	Geo	Hydro	Ocean
Special Management Areas	✓	✓	✓	✓	✓	✓
Stream Gauges					✓	
Streams with Aquatic Resources			✓		✓	
Streams with Cultural Resources			✓		✓	
Streams with Riparian Resource			✓		✓	
Submerged Buoys						✓
Submerged Cables						✓
Threatened & Endangered Plants	✓	✓	✓	✓	✓	
Tsunami Evacuation Zones	✓	✓	✓	✓	✓	✓
Unexploded Ordnance						✓
Very Generalized Vegetation	✓	✓	✓	✓	✓	
Volcano Boundaries				✓		
Volcano Hazard Zones	✓	✓	✓	✓	✓	✓
Water Quality Classifications					✓	
Water Quality Monitoring Sites					✓	
Watersheds	✓	✓	✓	✓	✓	✓
Wetland	✓	✓	✓		✓	
Wrecks						✓

Figure 3 provides an example from I-Map Hawaii's download section, providing snapshots of the various GIS data available, showing the hillshades, elevation, National Marine Humpback Whale Sanctuary, and parks layers on Kauai. This map can assist renewable energy developers in identifying land or ocean areas to avoid due to parks, terrain features, or existing uses that may be incompatible with specific technologies.

I-Map Hawaii also allows users to zoom into specific areas, click on features and obtain information from the selected "active" layer. Full instructions for using the viewer are located at www.hawaii.gov/dbedt/gis/I-Map_Hawaii_Instructions.pdf.

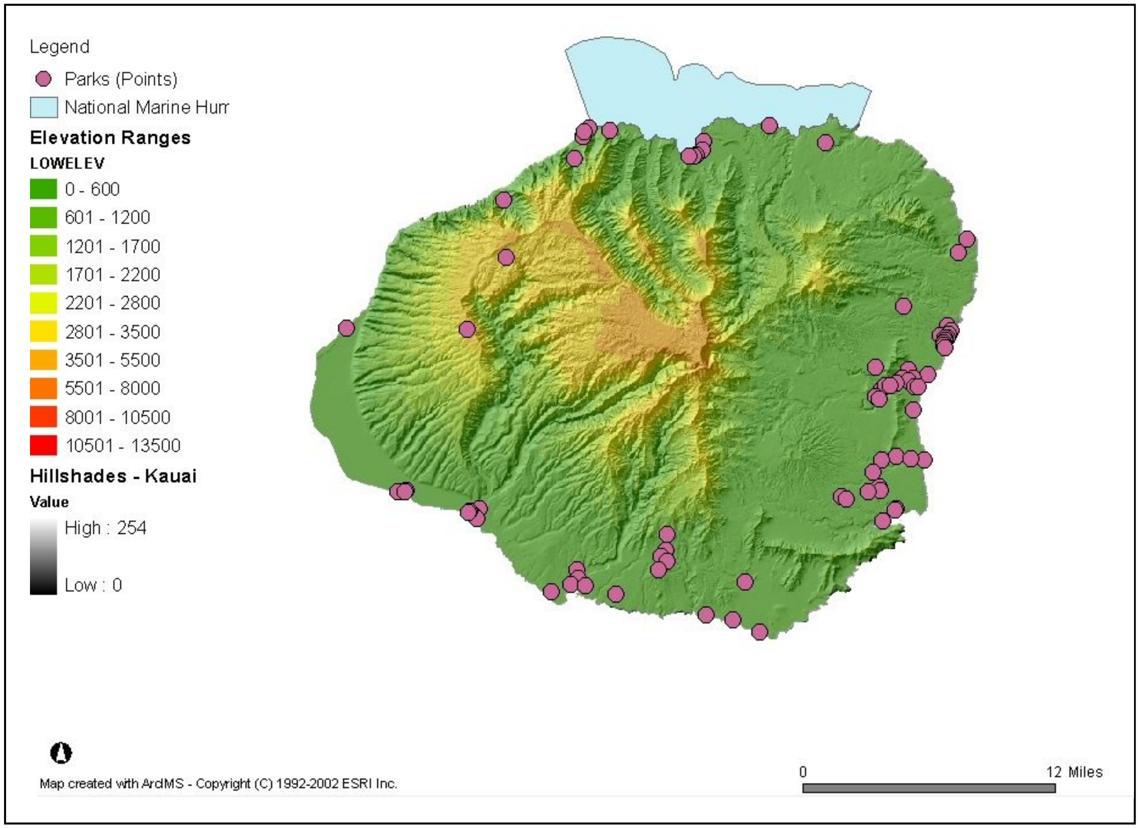

Figure 3. I-Map Hawaii Example Output for Kauai Parks

Hawaii Biomass Resources Viewer

Layers relevant for biomass and municipal solid waste energy development are provided in a separate GIS viewer, available at http://gis.hawaii.gov/website/biomass. The interface works the same as I-Map Hawaii, but contains land use designations, zip codes, and the following additional layers:

- Ag wastes
- Animal wastes
- FOG (fat, oil, and grease) waste
- Food waste
- Landfills
- Roads
- Transfer stations
- Waiakea Timber Management Area
- Waste water treatment plant

Online GIS Maps

The Hawaii State Office of Planning's GIS website includes a page with prepared map images based on 2000 Census data as both GIF and PDF files (www.hawaii.gov/dbedt/gis/miscmaps.htm). Enterprise zone maps for the state and the individual islands are provided in an html format. Agricultural land use maps are available in PDF format.

The following are also available for the state and individual islands:

- Agricultural Lands of Importance to the State of Hawaii (ALISH) maps
- Land Study Bureau maps
- Large Land Owners maps
- Natural Reserve maps (i.e., federal and forest lands, wildlife and historic preserves, parks)
- State Land Use Boundary maps (i.e., zoning)
- Watershed Boundaries maps

Most of these maps are created for both small (8.5" x 11") and large format reproduction (e.g., 24" x 36"); however, they do not contain a lot of detail, so zooming into a specific area does not reveal more information.

As an example, Figure 4 shows an overview map of Hawaii's state and federal reserve lands, including military and forest lands as well as bird sanctuaries and recreation areas.

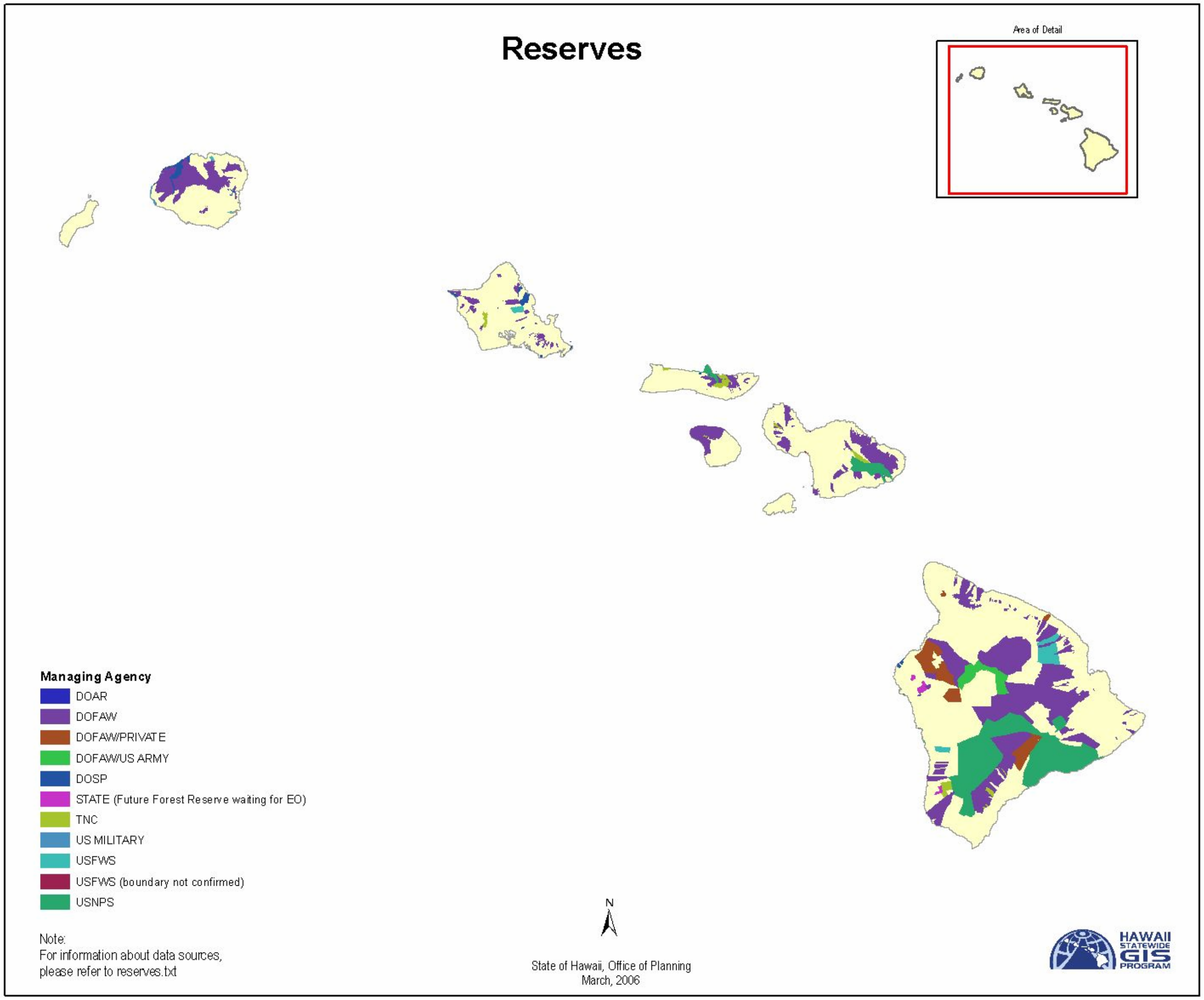

Figure 4. Hawaii State and Federal Reserve Lands
Includes military and forest lands, as well as bird sanctuaries and recreation areas

4. Land Availability and Development Considerations

This section of the Catalog includes information that is pertinent for all renewable technologies including a summary of major renewable energy assessment work that has been completed in Hawaii, discussions of zoning and permitting requirements, and a description of land use and ownership.

Assessments Available

A number of major public information sources document previous renewable energy siting work completed in Hawaii. These efforts, published by utilities, state agencies, and universities, each address several different renewable energy technologies available in Hawaii and are summarized below. Specific project sites identified in these studies are listed by technology under Section 5 of the Catalog.

The primary source of comprehensive renewable energy information is the *Hawaii Energy Strategy (HES) 1995 Renewable Energy Assessment and Development Program*, also known as Project 3. It is a comprehensive assessment of Hawaii's renewable energy resources — wind, solar, biomass, hydroelectric, ocean thermal energy conversion, geothermal, and wave energy — and a long-range development strategy. The *HES 1995* project consisted of three phases, summarized in three reports produced by RLA Associates, which evolved into Global Energy Concepts.

Renewable Energy Resource Assessment Plan: Phase I reviewed the activities involved in creating the resource assessment plan, including determining constraints and requirements, identifying potential project sites, analyzing existing utility infrastructure, identifying existing monitoring sites, and screening potential sites. New solar and wind monitoring sites were recommended and instrumented for collection of additional data.

Development of Renewable Energy Resource Supply Curves: The Phase II report compiled cost and performance data on current and future renewable energy conversion systems, analyzed and reduced existing data on available resources, and presented the renewable energy resource supply curves, which were developed. A computer model was developed to allow comparison of cost information on renewable resources with various alternatives.

Renewable Energy Integration Plan: Phase III completed collection of a year's worth of wind and solar data, updated the resource supply curves to reflect the additional data, and developed a plan to integrate the most cost-effective renewable energy projects into Hawaii's energy supply mix. Viable renewable energy projects were prioritized by technology and project site for each of Hawaii's four major islands.

The combined 590-page Hawaii Energy Strategy report is available online at: www.hawaii.gov/dbedt/info/energy/publications/index_html#1995.

Global Energy Concepts updated the renewable energy characteristics and performance information in 2000 and 2004. The 2004 update, entitled Select Renewable Energy Cost and Performance Data, is available on the DBEDT web site at: www.hawaii.gov/dbedt/info/energy/publications/shrep04.pdf.

Each of the four Hawaii utilities is required to periodically produce integrated resource plans (IRP) describing its future plans for supplying electricity to its customers by evaluating the current resources, load, and transmission capability versus forecasted load growth. HECO's Final Preferred Plan for the 2006-2025 planning horizon calls for approximately 151 MW of energy efficiency, conservation, and other demand-side management programs; 50 MW of combined heat and power and distributed generation resources; 1.2 MW of photovoltaic resources, of which 300 kW is targeted for accelerated installation in 2007; and 50 MW of wind power is planned for 2009. HECO's full 509-page 2005 IRP is available at: www.heco.com/images/pdf/HECO_IRP3_Final_Report.pdf.

HELCO and MECO are nearing the end their third IRP process. This multi-year effort will result in a 20-year plan that includes consideration of both demand-side and supply-side options. HELCO is scheduled to submit its IRP in December 2006 and MECO's IRP is scheduled to be completed in early 2007. Additional information on the most recent advisory group and public meetings, as well as previous IRP and PUC documents, is available at www.helcoirp.com and www.mauielectric.com.

KIUC, plans to complete part of its IRP by the end of 2006. The cooperative conducted a comprehensive evaluation of the potential for renewable energy. The *Kauai Island Utility Cooperative: Renewable Energy Technology Assessments* (2005) identifies potential project locations and sizes, and assesses the feasibility of the five most promising near-term renewable energy technologies located on Kauai, ranked as:

- Hydroelectricity
- Wind
- Municipal Solid Waste (biomass)
- Landfill gas (biofuel)
- Biomass

After screening 26 renewable and advanced energy technologies, the study found that these commercially available resources could reduce or eliminate Kauai's dependence on fossil fuels for electricity production. Moreover, developing these indigenous resources is expected to cost less than the current avoided cost of energy on Kauai. The economic analysis presumed that all projects come online in 2009. The report is available online at www.kiuc.coop/indexabout.htm.

The primary objective of the Hawaii Energy Policy Forum study, *Renewables and Unconventional Energy in Hawaii*, published by the University of Hawaii at Manoa's College of Social Sciences in 2003, was to develop and evaluate a working database of potential wind, solar, and biomass projects for the generation of electricity in the state. The results included a strategy to phase renewables into Hawaii's electric utility grids; an evaluation of the potential for alternative public policy options to facilitate the implementation process; and a preliminary assessment of the overall economic impacts on the state. The full 322-page Hawaii Energy Policy Forum report is available online at: http://hawaiienergypolicy.hawaii.edu/papers/bollmeier.pdf.

Overview of Hawaii's Renewable Energy Resources

Physical characteristics of the land and coastlines, the magnitude of the available renewable resources, and the energy needs and infrastructure of each island impact the viability of renewable energy projects. Table 4 shows the most promising renewable energy technologies by island based previous assessments. Additional comments on each island are included in the following paragraphs.

Table 4. Most Promising Renewable Energy Technologies by Island

	Wind	Solar	Biomass	Geo	Hydro	Ocean
Island of Hawaii	✓	✓	✓	✓	✓	✓
Oahu	✓	✓	✓			✓
Kauai	✓	✓	✓		✓	✓
Maui	✓	✓	✓	✓	✓	✓
Molokai	✓	✓				
Lanai	✓	✓				

The Island of Hawaii

As the island's nickname "Big Island" suggests, abundant land is available suitable for renewable energy development. Bigger than all of the other islands combined, the Island of Hawaii features large areas with sufficient renewable energy resources for development identified through the screening processes described above. The value of renewable energy generation is limited more by the size of the utility load, the shape of the demand curve, and the need for transmission infrastructure than by any other factor. The electric load is growing most rapidly and projected population and economic growth is greatest on the sunny, western side of the island where large hotels and tourism drive the demand.

However, most of the existing generation is located on the wetter, eastern side of the island and connected to West Hawaii by long, relatively small capacity transmission lines. In addition, most renewable resources are well away from load centers. As a result, the utility is concerned about interconnection of intermittent renewable energy projects at weak points on the grid, among other technical issues.

Oahu

The island of Oahu, which is also the City and County of Honolulu, contains about 68% of Hawaii's de facto population. As such, there are significant competing land uses and a majority of Oahu's land may not be economically available for utility-scale renewable energy development. Associated with its large population, tourist industry, and industrial sector, Oahu has by far the largest island electrical utility system. Because of its large load, the penetration of intermittent generating sources is less of a problem than on other islands. However, with its high competition for land available for development and protected natural features, it is much more difficult to identify ideal sites for renewable energy projects on Oahu than on the other islands. Nonetheless, the potential is high for certain projects on land that is already commercially developed or under development, such as solar applications installed on rooftops of government, commercial, or industrial facilities.

Kauai

The central mountain regions of Kauai are zoned as Conservation land and are largely park and forest reserve lands. These areas are also virtually physically inaccessible for renewable energy project development. Development of utility-scale renewable energy on the north side of the island could be challenging due to zoning, terrain constraints, and lack of grid access. The majority of Kauai's remaining land is coastal areas with either urban or tourist development. The population density of Kauai is highest at Lihue and Kapaa on the eastern side of the island, and the majority of the land in this area is already committed to other uses. In any event, finding a location for land-intensive energy projects near the energy load on Kauai may be difficult. Limited resource data for wind, biomass, and hydroelectricity on Kauai are available.

Maui

The mountain regions of Maui are also zoned as Conservation land, and most of the major mountain, Haleakala, is largely national park and forest reserve lands inaccessible for energy project development. The south side of Haleakala to the coast and the northeast side of the West Maui Mountains could be used for renewable energy, but sites are limited by terrain constraints and lack of utility access. The majority of Maui's remaining coastline is developed for tourism. However, some suitable land does exist with sufficient resources for utility-scale development of a full range of renewable energy technologies along certain ridges and in the center of the island.

Molokai and Lanai

Molokai and Lanai are part of Maui County and are served by MECO. Both islands are small in relation to the other Hawaiian Islands with small populations and relatively small electricity loads. While large areas with development potential for renewable energy projects exist on each island, electricity demand does not justify large-scale projects.

Renewable energy development on these islands can be more appropriately incorporated through demand-side measures such as solar hot water heaters and small-scale, dispersed generation projects such as wind-powered water pumping and residential wind turbines.

Zoning & Permitting Issues

There are a variety of permits required for any development on land or in the ocean in the State of Hawaii. Some are required by the federal government, others by the State, and still others by the four counties.

As a general rule, the federal government's regulatory role applies to work in navigable waters, as well as around airports and related facilities and the protection of wetlands. Activities regulated by the State focus on public health, welfare, and the management of natural and human resources. Counties regulate activities that are more directly related to land use, zoning, and development of facilities, including building, grading, and construction controls. Project developers are advised to contact the county agencies listed in Section 6 for guidance on county permits.

Regulatory responsibilities in some instances overlap or are shared among the various agencies. Accordingly, a proposed project may require the permission of only one or all three tiers of government. One example of shared responsibilities is the Hawaii Coastal Zone Management (CZM) Program. The counties administer a permit system for some types of development within designated special management areas (SMAs) along the shoreline, which the State must monitor to ensure compliance with statewide CZM objectives and policies. Information on SMAs can be found on the Department of Business, Economic Development, and Tourism website at www.hawaii.gov/dbedt/czm. A PDF document entitled, "Participant's Guide to the SMA Permit" provides useful information, including contact information for the appropriate agencies.

There is also shared management responsibility among all three levels of government relating to environmental matters. The federal government has transferred regulatory authority for some environmental matters, such as the Clean Water Act, to the State. Similarly, some of these regulatory responsibilities have been transferred to the counties.

The State Department of Forestry and Wildlife (DOFAW) will provide general comments to potential site data that can be used to plan renewable energy projects. Historically, DOFAW reviews projects based on its environmental impacts to endangered flora and fauna since most requests occur outside of its primary forestry and wildlife management responsibilities. All renewable energy projects must consider the potential impacts on endangered species, critical habitat, migratory birds and conservations districts. Such projects

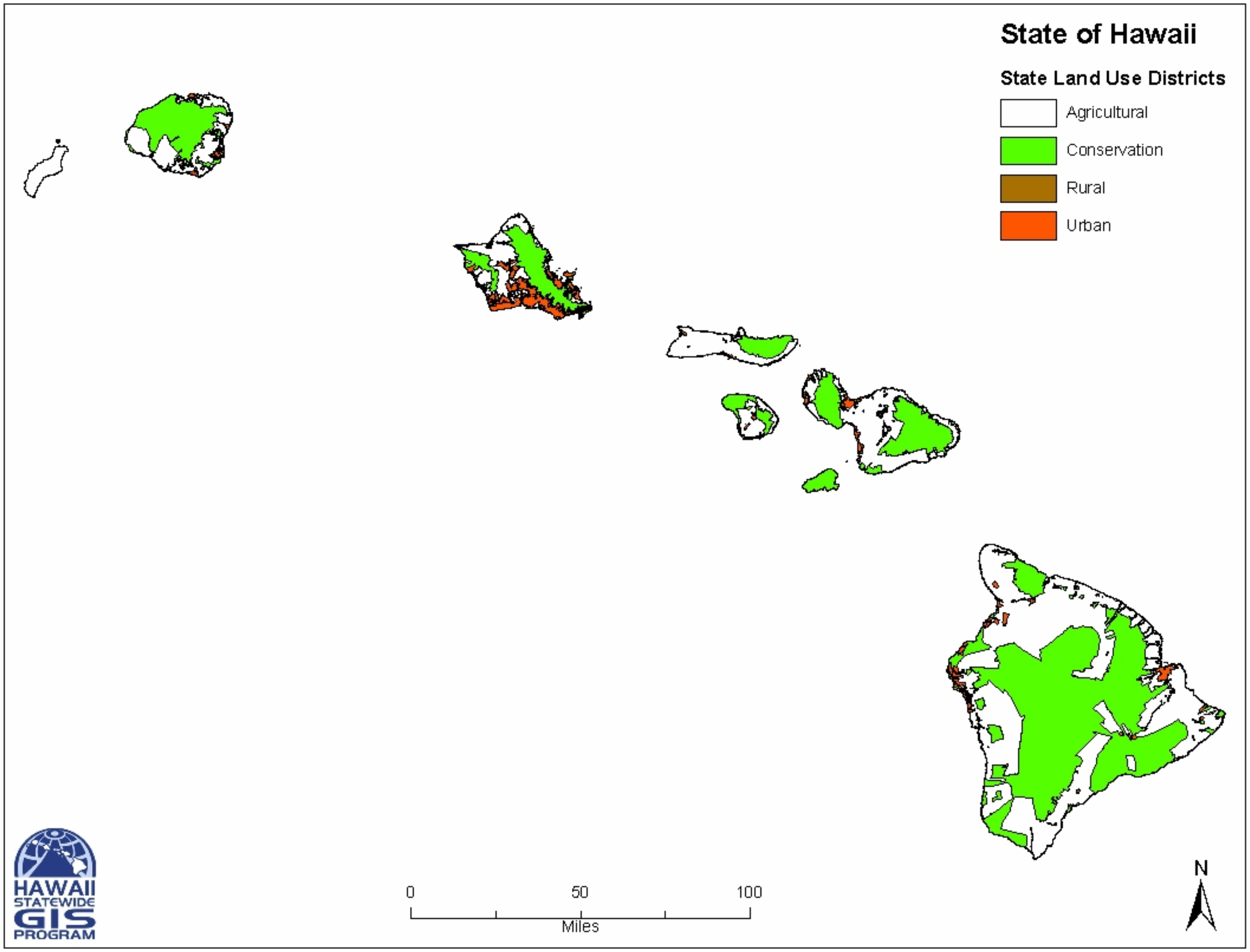

Figure 5. State Land Use Districts

will need to avoid impacts on endangered species as much as possible, and go through the necessary permitting process for habitat conservation plans and incidental take permits or other regulatory permit process. Permitted uses under the State Land Use Commission and its state-wide zoning authority will determine the appropriateness of renewable energy projects and its impact to the environment. Renewable energy projects in forest reserves, natural area reserves, game management areas, wildlife sanctuaries, and Na Ala Hele trails are also subject to statutes and administrative rules administered by DOFAW.

The Hawaii Environmental Impact Statement law requires a process and hierarchy of environmental impact thresholds for all renewable energy projects using state lands or funds. It also requires public disclosure of and participation in such projects that may have environmental consequences on the natural resources.

Hawaii's state-wide system of land zoning defines land districts as Urban, Rural, Agricultural, or Conservation, shown in Figure 5. Conservation districts are further divided into Undesignated, General, Limited, Protective, Resource, and Special subzones. Land in any type of zoning district may be further classified as Shoreline. Federal land that is zoned Urban and used for military purposes may be available for renewable energy development consistent with current land use practices.

Each of Hawaii's land use districts and subzones has specific regulations for allowable land uses and the permitting processes required, and their boundaries are periodically reviewed by the Hawaii State Office of Planning. The modification process allows the state to encourage or discourage various land use activities, so future policy or legislative changes could make more land available for renewable energy development. Zoning information pertinent to the various renewable energy technologies is discussed below.

Wind: Specific wording allows wind energy development in Hawaii's Agricultural districts, and barring conflicting land uses, wind energy is likely to be allowable in rural districts. It is foreseeable that permits would be granted for wind energy projects to be developed in Conservation district subzones designated Resource and General.

Solar: Distributed solar energy systems are typically compatible with urban development, and utility-scale solar developments are anticipated to be allowable in rural districts. Commercial solar projects could also likely be developed in Agricultural districts where the soil is of quality C, D, E, or U, denoting limited value according to the Agricultural Lands of Importance to the State of Hawaii (ALISH) system, as well as in Conservation district subzones designated Resource and General.

Biomass: Only land currently zoned for Agriculture is likely to be available for dedicated energy crops. For municipal and organic solid waste projects, land zoning is not a determining factor. The land requirements for a processing facility will be driven by the waste stream, and with the exception of protected Conservation land, waste-to-energy and other bioenergy projects should be feasible to site in any zoning category including Urban land where sufficient feedstock volume is available within an economical hauling distance.

Geothermal, Hydro, and Ocean: Although the plant footprint of geothermal, hydro, and ocean energy facilities may not be large, actual or perceived environmental impacts may be substantial and projects could face significant public opposition in the permitting phase. The State of Hawaii has established geothermal subzones. The majority of Hawaii's hydro resource is located within Conservation districts. Land-based wave and ocean thermal energy conversion facilities, by definition, are located in areas classified as Shoreline. Access over or under the beach for pipes is needed for ocean thermal energy conversion and for power lines for wave and ocean current energy. Ocean energy or offshore wind development would likely occur in "submerged lands", considered to be Conservation districts. Due to the high value of shorelines, sites considered for ocean energy development are likely to be based on the existing land use conditions rather than zoning.

Cultural sensitivity or NIMBYism (Not In My Back Yard) can lead to opposition to certain technologies. As of this writing, there is a history of significant opposition to geothermal development on the Island of Hawaii, hydroelectric development on Kauai and the Island of Hawaii, and to proposed wind farms at Kaena Point and above Kahe on Oahu.

A detailed discussion of these topics is not included in this Catalog. However, the contacts provided in Section 6 are excellent resources for helping to determine potential local concerns and what steps need to be followed for renewable energy project development.

Land Ownership & Uses

With limited availability of land on most of the Hawaiian Islands, energy production must compete with diversified agriculture, military uses, housing developments, golf courses, tourist resorts, grazing, and environmental and cultural preservation. Nevertheless, some renewable energy technologies can share land resources with other uses, such as wind turbines in grazing, many types of agricultural areas, and on conservation lands.

Land ownership can be determined from the Large Land Owner maps at www.hawaii.gov/dbedt/gis/large_landowners.htm. Tax key maps available as GIS layers, downloadable images, or hard copies from county offices can provide more detailed information regarding ownership of specific parcels and private land. Renewable energy development in Hawaii is highly dependent on the project's effect on the overall income of the landowner and how it affects the profitability of planned land uses of surrounding lands. Most power generating technologies are not directly compatible with tourism activities, so a landowner that plans a vacation resort is often unwilling to agree to site an energy project on nearby land. However, some landowners planning resort areas have expressed an interest in renewable energy projects on their property as part of diversified land use planning.

Due to the concerns of many private landowners in Hawaii, state or federal lands are attractive as potential energy project sites. These lands generally require more permits for project development and will usually be leased at fair market value.

The State Land Use District Boundary Review reports for each island can be reviewed to determine the rationale for any potential land use re-classifications that may be undertaken by the State. The majority of the large landowners in Hawaii have long-term land use plans for the lands under their control. Another factor to consider when seeking to replace existing agricultural crops with more industrial energy projects is that Agricultural lands are often seen as a buffer between urban developments and areas used for conservation and tourism.

Wind Energy

Wind development is compatible with some agricultural uses, as turbine foundations physically occupy only a small fraction of the project site's land area. The area between wind turbine foundations can be used for grazing or, in some cases, crop cultivation. Hawaii's two main crops, sugar and pineapples, entail harvesting techniques not as compatible with wind energy compared to many other crops. The open burning of cane fields to remove debris after harvest may pose a risk to wind turbines. However, since the decline of the sugar industry in Hawaii, the use of many former sugar fields has changed. The new uses may be more compatible with wind development. Grazing is considered to be compatible with wind energy, as has been demonstrated on the Island of Hawaii at the Lalamilo Wells wind farm, at Hawi, and at the Kahua and Parker Ranches.

Solar

Due to its land-intensive nature, utility-scale solar energy development may be incompatible with many agricultural uses. Concentrating solar technology may be compatible with some grazing uses. However, the reflection from solar projects must be considered so that it does not interfere with nearby activities, such as airfields.

Distributed solar energy projects such as solar water heating, photovoltaic (PV) lighting, PV rooftop systems, and building-integrated PV can integrate easily with other land uses and developments. One prime example is the Mauna Lani resort on the Island of Hawaii which boasts the distinction of having the most solar electric generating capacity of any luxury resort in the world, over 500 kW of PV systems; described at www.maunalani.com/r_hc_overview.htm.

Bioenergy

The economic feasibility of dedicated energy crops depends largely on factors in the sugar, pineapple, and oil markets, in addition to alternative uses for land. Energy production from organic waste conversion is not as land intensive as energy crop production and is not as significantly impacted by competing land uses. Depending on the technology employed, the by-products from organic waste processing may be desirable for agricultural purposes. It may be advantageous to locate waste-to-energy conversion facilities near to or on agricultural lands. Because the low concentration and cost of transportation of organic waste is a primary consideration in Hawaii, facilities are likely to be centrally located near existing landfills to take advantage of the waste disposal transportation strategies in use. Since municipal solid waste and landfill gas projects are co-located at transfer stations or landfills, competing land use should not be an issue when siting these projects.

Geothermal

The Board of Land and Natural Resources (BLNR) is charged with the responsibility of designating and administrating Geothermal Resource Subzones in which geothermal development for electricity production can take place to help meet the State's energy objectives. These Resource Subzones may exist in any of the four land use districts of the state (urban, rural, agriculture, and conservation). The Island of Hawaii's primary geothermal development site, the Kilauea East Rift Zone (KERZ), is zoned for both Agricultural and Conservation uses in about equal proportions, with a minor amount of urban land. The area's Conservation land is mainly on the western portion of the KERZ including the Hawaii Volcanoes National Park. The middle and lower subzones of the KERZ are predominantly Agricultural, which includes some state land. Additional information on the state policies governing the Geothermal Resource Subzones, as well as factors and key issues impacting the designation of subzones is included in http://www.hawaii.gov/dbedt/info/energy/publications/georesource00.pdf.

Hydroelectricity

Hydroelectric power development is seen by some as competing with environmental preservation and recreation. Public opposition due to these factors is a major consideration for siting hydro projects, and the primary factor likely to limit additional large-scale hydropower development in the state. All projects currently in operation are run of the river; however, several pumped storage facilities have been proposed in the past and one is under active consideration on Maui.

Ocean

The primary conflicting land use for any land-based ocean energy system is access and use of the shoreline. The islands' shorelines are very valuable for tourism and other ocean access activities, so the future development of ocean thermal, current energy, and wave projects could face challenges unless they are located in areas where they do not compete. However, the shoreline may not be the primary conflicting location for ocean energy. Use of the ocean surface and subsurface may also come into contention, possibly conflicting with uses, including shipping lanes, recreational uses, military testing, fishing, and marine animal habitat. If the ocean energy units are visible from on shore, there may be opposition on aesthetic grounds.

5. Existing Projects and Potential Sites

This section of the Catalog is organized by technology and documents existing renewable energy projects and potential sites that have been previously identified through publicly available siting studies. Descriptions of the anticipated resource for each technology, maps using the State's publicly available GIS data, and additional resources that may be helpful in siting projects are included.

The following resources are covered in this section:

- Wind
- Solar thermal
- Photovoltaic
- Biomass, biofuels, and biogas (produced from dedicated energy crops, agriculture and food processing waste, municipal solid waste, landfill gas, and other sources)
- Geothermal
- Hydroelectricity
- Ocean energy (including wave energy, energy from ocean currents, and ocean thermal energy conversion)

Tables are included for each energy source providing summary information for potential development areas. Most of the sites are identified primarily in the three studies described in Section 4. Further details on the potential sites are available by accessing the reports at the websites shown:

- Hawaii Energy Strategy, 1995 (HES) *Renewable Energy Assessment and Development Program* www.hawaii.gov/dbedt/info/energy/publications/index_html#1995
- Kauai Island Utility Coop, 2005 (KIUC) *Renewable Energy Technology Assessments.* www.kiuc.coop/indexabout.htm
- Hawaii Energy Policy Forum, 2003 (HEPF) *Renewables and Unconventional Energy in Hawaii* http://hawaiienergypolicy.hawaii.edu/papers/bollmeier.pdf

For each site identified in this section, comments are made regarding transmission and other qualitative factors. Most of the transmission information in the tables is taken from the 1995 HES study; therefore, developers should confirm the location and capacity of transmission lines as part of determining whether or not to pursue a particular area for development. Generally there have not been major changes to transmission systems. Other comments are meant to guide developers by providing context and other observations; however, all information should be independently verified.

Wind Energy

Each of Hawaii's islands has some amount of wind resource potential.

Island of Hawaii: Trade winds are diverted around the island's two tallest volcanoes, Mauna Loa and Mauna Kea, resulting in acceleration to the north of Mauna Kea through the Waimea saddle and over the Kohala Mountains, producing several areas of significant wind resource. To the south of Mauna Loa, the wind diversion produces a smaller area of significant wind resource at the southern point of the island.

Oahu: The Koolau Mountains and the Waianae Range enhance Oahu's trade winds. The northeastern (Kahuku), southeastern (Koko Head), northwestern (Kaena Point), and southwestern (Kahe) tips of Oahu have areas of substantial wind resource. The best potential combination of land available for wind development and a strong, proven wind resource is found in the Kahuku area.

Kauai: Trade winds flow around the central mountain mass of Kauai. The prime wind resource appears to be on the southeastern and northeastern coasts of the island. Most of Kauai's coastal areas are either developed for tourism or planned for urban expansion. However, there has been limited wind resource data collection on Kauai.

Maui: The primary wind resource on Maui lies in the central valley where the trade winds accelerate between the barriers of Haleakala and the West Maui Mountains. Wind potential also exists in the northwestern slope of the West Maui Mountains and of lower Haleakala.

Lanai: Lanai lies partly in the wind shadow of West Maui. Nevertheless, there appears to be some wind resource on the northwestern third of this island.

Hawi Renewable Development LLC Wind Farm at Upolu Point near Hawi on the Island of Hawaii. Source: Hawaiian Electric Light Company via NREL Photo Information Exchange.

Molokai: Molokai is unique among the Hawaiian Islands in that its topographical orientation lies almost parallel to the prevailing trade winds Exposed areas on most of the island are estimated to have significant wind resources, with the most substantial wind resource being located in the northwestern corner.

Hawaii's wind power resource map, created as part of a cooperative effort involving the U.S. Department of Energy's Wind Powering America program, HECO, and DBEDT, is shown in Figure 6. As a means of promoting wind energy development, the National Renewable Energy Laboratory teamed with AWS Truewind to develop high resolution wind maps for Hawaii and other selected states using Meso mapping techniques that rely on upper atmospheric air data extrapolated to near ground elevations. Figure 6 shows wind power at 50 m above ground level with a 200-m grid resolution. GIS data layers and individually prepared wind speed maps for each island at 30, 50, 70, and 100 m above ground level are available at www.hawaii.gov/dbedt/info/energy/publications/winddata/.

Installed and Planned Wind Energy Projects

Hawaii was a pioneer in the installation of wind turbines. However, some of the early technology that was deployed in the state was not well suited to the environment and/or experienced reliability issues that likely discouraged additional investment in wind energy for many years. As a result, the list of existing wind energy projects in Hawaii (Table 5) includes only one project using older technology remaining from several installed in the 1980s and new projects recently commissioned or under development. A handful of small-scale projects (1 MW or less) are included on the list because they are commercial installations. There are some small-scale "residential" wind applications that are not included here.

The Island of Hawaii has the largest number of projects installed and planned. The projects are at Upolu Point near Hawi at the northern end; at South Point, the southern tip of the island; and in the saddle area between the two mountain peaks at Lalamilo Wells. As would be expected, these areas were predicted to be windy areas on the wind map. Their original development size was somewhat dictated by nearby transmission capacity. The Pakini Nui project at South Point is replacing the original Kamaoa project, which was dismantled in 2006.

On Maui, the 30 MW Kaheawa Pastures project began operation in 2006 and is located in a documented high wind area on Maui, giving Maui the most operational wind capacity in the State as of the end of 2006. Another 40 MW wind farm, the Auwahi wind project on Ulupalakua Ranch, is proposed is in what appears to be a low wind resource area on the wind map; however, site wind speeds are reported to be greater than those shown on the map due to local terrain features that accelerate the wind. Recent announcements on this project indicate that the developer is exploring the potential for incorporating pumped hydro storage with wind energy, which could increase the value of the project by storing wind power generated during off-peak electric periods by pumping water uphill into a reservoir and then recapturing the energy by releasing the water through a hydroelectric generator to a lower reservoir to help meet peak demands.

On Kauai, a power purchase contract was signed for a wind project in 2003; however, the project developer could not reach an agreement with the landowner of their originally proposed site and is thus investigating alternative sites.

On Oahu, a wind project installed in the 1980s operated for several years and included the prototype Boeing MOD-5B, a 3.2 MW wind turbine developed with support by the U.S. Department of Energy and 15 600 kW Westinghouse units, totaling 12.2 MW. Because that project ceased operation in 1996, it is not included in Table 5; however, the former site at Kahuku is under consideration for a new wind project. In 2005, HECO sought to develop another site on Oahu above Kahe but dropped its efforts due to local opposition on aesthetic and cultural grounds.

Molokai also had a small experimental wind project consisting of three 100 kW wind turbines coupled with a diesel unit in 1992. That project was dismantled following a lightning strike which damaged the facility after several years of operation.

Proposed and installed large-scale wind energy projects are regularly updated at www.awea.org/projects/hawaii.html.

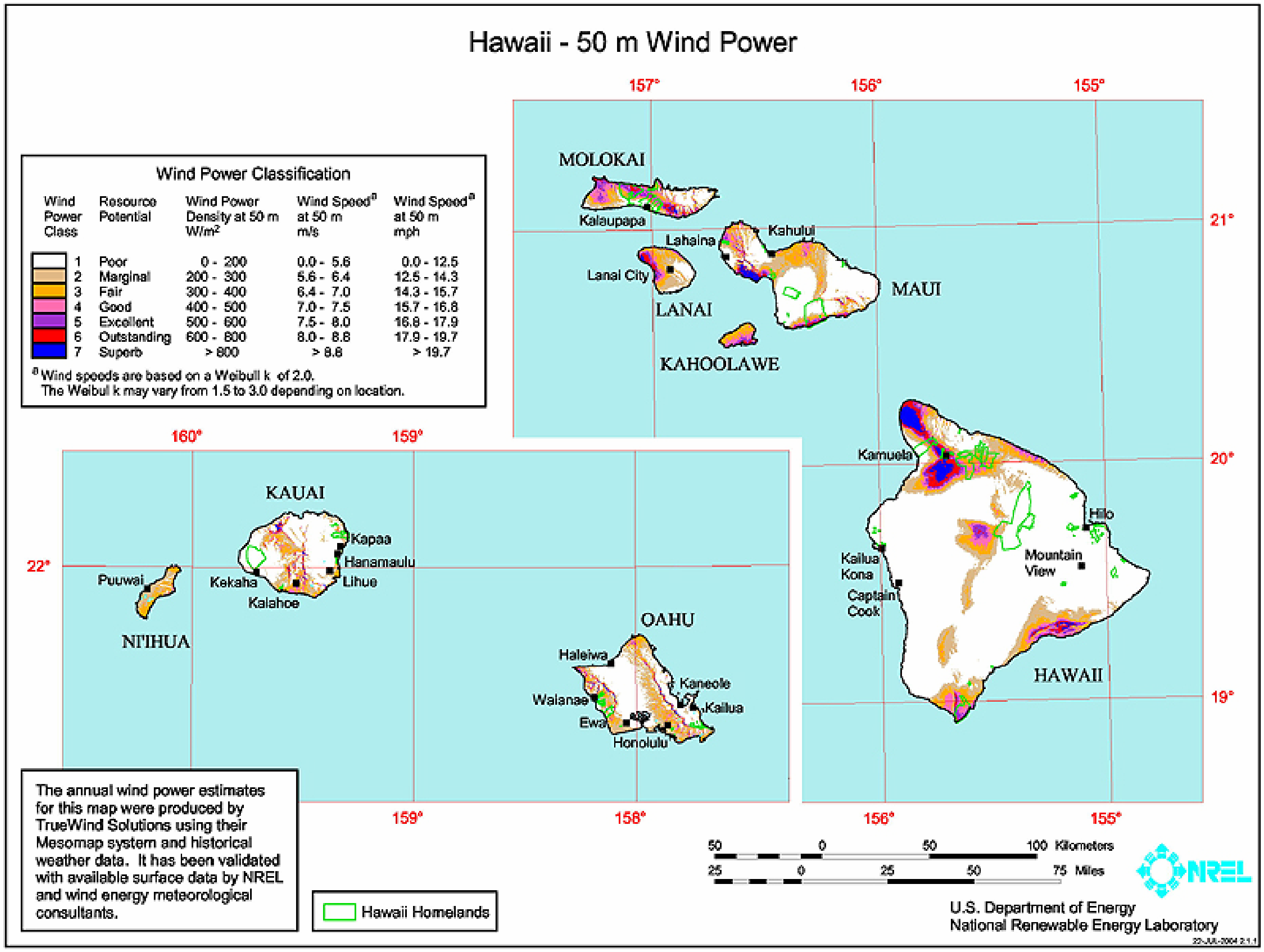

Figure 6. Hawaii Wind Power Map

Table 5. Installed and Planned Wind Energy Projects in Hawaii

Location	Project	Information
Island of Hawaii		
Kamuela	Parker Ranch	50 kW (wind/PV hybrid) 5 – 10 kW Bergey
South Point	Pakini Nui	20.5 MW (expected to be online in 2007) 14 – 1.5 MW GE
Upolo Point	Hawi	10.56 MW (online 2006) 16 – 660 kW Vestas
Waikoloa	Lalamilo Wells	1.56 MW (installed 1985) 26 – 17.5 kW Jacobs, 55 - 20 kW Jacobs
Kauai		
TBD	Kauai Wind Farm	10.5 – 15 MW (contract awarded)
Maui		
Ukumehame	Kaheawa Pastures	30 MW (online 2006) 20 – 1.5 MW GE
Ulupalakua Ranch	Auwahi Wind Project	40 MW (early planning stages)

Prime Wind Development Areas

Table 6 is a compilation of information on promising wind project areas in Hawaii. Many of the areas listed are near existing or previous projects, but they are included in this table because additional capacity could be added to the sites in the future.

The table covers general location, resource information, and other observations. The resource column includes known, publicly available data as well as general comments on the known or suspected wind resource. DBEDT has collected the publicly available wind data and has made them available online at www.hawaii.gov/dbedt/info/energy/publications/winddata/.

Other Wind Energy Development Potential

There is significant potential for small or distributed wind energy projects throughout the Hawaiian Islands. The economics and required wind resources for small-scale projects differ from utility-scale development options. The American Wind Energy Association's website includes a broad range of information on developing small wind in Hawaii at www.awea.org/smallwind/Hawaii_sw.html.

Offshore wind energy development is receiving considerable attention in Europe and, to a lesser degree, on the Mainland. The wind maps developed for Hawaii also include estimates of offshore wind resources. However, due to the volcanic origin of the islands, in many of these locations, the ocean shelf drops off significantly near shore. Technologies for deep water offshore wind are under development, but not yet available. HECO has conducted some investigation of offshore wind potential on Oahu but no projects have been discussed to date. Additional information on bathymetry (ocean depth) is included in the ocean technologies section which could assist developers interested in offshore wind projects to identify sites.

Table 6. Previously Identified Potential Wind Development Areas

General Location	Resource	Terrain	Other Comments
Island of Hawaii			
Kahua Ranch: On the Kohala ridge line, formerly the site of a small wind farm	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/	Rolling hills	A number of different wind turbines have been installed at this site over the last 20 years. A 10 MW wind project was approved by the PUC and a power purchase contract was signed in 2001; however, the contract was cancelled. The wind farm at Upolu Point is using existing transmission capacity that would be used by a wind farm at Kahua Ranch and additional capacity would be required for a project at Kahua.
Lalamilo Wells: Located in the plains between Kohala and Mauna Kea, the site of existing 1.6 MW wind project owned by HELCO	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/ A summary of additional data (collected by a private developer) is included in the HES data report.	Gently sloping	Large area with significant potential, near load growth. Several wind developers have also monitored the area and proposed projects. HELCO has indicated that it is examining repowering its wind farm at Lalamilo. Transmission upgrades would be necessary for large development.
North Kohala: Located in the lowland area of North Kohala, near the town of Hawi	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/	Gently sloping	Location of the Upolo Point 10.56 MW project. One of the strongest wind resource areas identified in HES 1995.
South Point: Location of dismantled Kamaoa wind farm and new Pakini Nui wind farm	No publicly available data but the success of the Kamaoa project, observed wind effects on vegetation, and topography indicate significant resource	Gently sloping	Contract for 20 MW replacement wind project was approved by the Public Utilities Commission in 2006. Construction has been initiated and the project is scheduled to be operational in 2007. Project will be interconnected to a spur line off the main circular transmission loop on the island.
Oahu			
Kaena Point	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/	Small area of high ground	Limited transmission in vicinity. Preliminary investigation in early 2000s met with community resistance on cultural bases.

Table 6. Previously Identified Potential Wind Development Areas

General Location	Resource	Terrain	Other Comments
Kahuku Hills or Kahuku Flats: Located on the northwest corner of Oahu	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/ Better resource in the hills than flats	Complex terrain in the hills; however, no problems are anticipated with construction or operation	Location of previous wind farm which included 15 600 kW Westinghouse units and the 3.2 MW MOD-5B, totaling 12.2 MW. Transmission in vicinity. HECO is seeking possible development of a new project at the site, which is now owned by the Army. Flats are used for fish and shrimp farming, which would be compatible with wind.
Kahe: Located in the ridges inland from the Kahe power plant	HECO collected data (not publicly available) following identification of area on wind map	Ridgelines	HECO proposed development of a wind project between 35 and 40 MW in this area following confirmation of the wind resource. In July 2005, HECO held a series of community meetings regarding the project. In September 2005, the Mayor of the City and County of Honolulu announced that his administration would not approve permits for this project based on concerns expressed at the public meetings. HECO withdrew its proposal.
Kauai			
Kalaheo: Coast and southwest of Kalaheo	Good winds shown on wind maps, no available data. Higher wind resource likely along the coast.	Relatively flat	Transmission in proximity to coast and Kalaheo. Relatively large amounts of land may be available in this area.
South of Kilauea/Anahola	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/ High winds measured at Kilauea Point Coast Guard Station. Wind is suspected to drop off considerably farther inland.	Varied	Several inland parcels south of Kilauea and in the Anahola area may be the only land available for a wind energy project.

Table 6. Previously Identified Potential Wind Development Areas

General Location	Resource	Terrain	Other Comments
Kokee: Straddling Highway 550, west of Waimea Canyon in Puu Ka Pele Forest Reserve	Good winds shown on wind maps; no available data.	Terrain may present construction issues	Near scenic highway and popular state park. Development limited to 2 MW without transmission upgrades according to KIUC's *Renewable Energy Technology Assessment*.
Mahaulepu: Extends inland from southeast coast and near major load centers of Lihue and Kapaa	Good winds shown on wind maps; no available data.	Steep ridgelines	Near transmission and load; however, there are areas of scenic and cultural significance in the vicinity.
North Hanapepe: North of Port Allen and Hanapepe	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/	Fairly complex. Mountain gorges thought to act as funnels, concentrating wind effects	Potential project sites are 3 to 5 miles from the nearest transmission line.
Omao	Good winds shown on wind map; no data available	Series of low ridges in the foothills north of Lawai	According to wind maps, the wind resources increase with distance from transmission.
Poipu	Moderate winds shown on wind map; no data available	Low lying, reasonably flat	Growing electrical load; significant tourist facility growth in this area.
Port Allen: Undeveloped land adjacent to Salt Pond Beach Park and Port Allen Airport	A summary of data collected by a private developer is included in the HES data report.	Flat, coastal	Land area is sufficient to site a small wind project; however, nearby helicopter activity may be an issue.
Lanai			
Inland from Shipwreck Beach: Southwest, non-coastal land near beach	Good winds shown on wind map, no available data	Gently sloping	No existing transmission lines in this vicinity and projected load growth is on the opposite side of the island.
Maui			
Northwest slope of Haleakala	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/	Gently sloping and rolling hills	Broad land area used for agriculture purposes. Some existing transmission in this area.

Table 6. Previously Identified Potential Wind Development Areas

General Location	Resource	Terrain	Other Comments
Southwest slope of Haleakala	No public data available	Gently sloping and rolling hills	Broad land area used for ranching and other agriculture. Ulupalakua Ranch, site of proposed 40 MW project, is in this area.
Ukumehame	Highest average wind speed recorded on Maui is at the southwestern corner of the isthmus at McGregor Point	Fairly complex; however, no problems anticipated with construction and maintenance	Location of existing 20 MW Kaheawa Pastures wind project; other areas with significant wind resource may be available in the general area. Location is relatively near MECO's Maalaea generating stations and load.
Puunene: In the center of the Maui isthmus approximately four miles south of Kahului	Data available at: www.hawaii.gov/dbedt/info/energy/publications/winddata/	Flat	Existing transmission lines in the vicinity. Old airport site.
West Maui	A summary of data collected by a private developer is included in the HES data report.	Fairly complex; however, no problems are anticipated with construction or maintenance	Good resource identified by private developer on ridgelines on the northwest slope of West Maui Mountains. Near load and transmission; potentially visible from tourist developments.
Molokai			
Ilio Point/West Molokai	Data collected 1/1/81-5/31/82 by U.S. DOE show excellent wind resource	Plateau	No transmission in this area and there is limited load on Molokai.

Programs to Stimulate Deployment of Wind Energy

Renewable Energy Income Tax Credits. The State of Hawaii offers individual and corporate state income tax credits for wind projects, which were made permanent and increased by the 2006 Legislature. Table 7 summarizes these credits.

Table 7. Hawaii Renewable Energy Income Tax Credits for Wind Energy Systems

	Maximum Tax Credit as Percentage of Cost	Maximum Tax Credit for Wind
Single-Family	**35%**	$ 1,500
Multi-Family	**20%**	$ 200
Commercial	**35%**	$ 500,000

Source: Act 240, SLH Hawaii

http://www.capitol.hawaii.gov/sessioncurrent/bills/SB2957_cd1_.htm

State Enterprise Zone Tax Credits. In addition, companies producing electric power from wind energy for sale primarily to a public utility company for resale to the public located in State Enterprise Zones are qualified businesses under §209-E1 through E10, HRS, and may qualify for a State business tax credit, credit against unemployment taxes, and relief from State excise taxes. Counties may offer local incentives, including reduction of permit fees; user fees, and real property taxes. Counties may also provide regulatory flexibility, including special zoning districts, permit process reform, exemptions from local ordinances; and other incentives.

For details, see www.capitol.hawaii.gov/hrscurrent/Vol04_Ch0201-0257/HRS0209E/HRS_0209E-0001.HTM.

Additional Wind Energy Information Resources

Aside from the Hawaii wind map data, the National Climatic Data Center (NCDC) maintains the world's largest active archive of weather data. NCDC collects all types of meteorological data from manual stations and Automated Surface Observing System (ASOS) stations; data can be purchased at www.ncdc.noaa.gov/oa/ncdc.html. All major U.S. airports and many regional U.S. airports have switched to ASOS and provide a consistent historical database, typically back to 1995-1996. Historical records go back much further and list every time the monitoring station equipment or position changed.

Topography is an important piece of information in evaluating a potential wind development area, both for sites listed below as well as additional areas. For example, steeper terrain in ridges may provide access to higher winds, but at increased costs. Topological maps and digital elevation maps are widely available at sites including www.hawaii.gov/dbedt/gis/, http://seamless.usgs.gov, www.terrainmap.com/rm39.html, and www.topozone.com; however, some features require a subscription. Digital elevation maps present elevation data as individual points of data, which can be used for viewing terrain in three dimensions, importing in GIS software for use with other layers, and other data manipulation.

Solar Thermal and Photovoltaic

Hawaii has excellent solar resources for rooftop photovoltaic (PV) installations, solar hot water heating, and other small-scale solar applications exist throughout the islands. Large-scale solar power plants (either solar thermal or solar electric) require significant land commitments and this section of the Catalog focuses on sites that have been identified for this type of solar application. Direct, rather than diffuse, solar radiation is necessary for optimizing the performance from solar power plants.

Direct insolation on the Island of Hawaii is greatest on the western side of the Island. Other areas offering a good solar resource, but with possible drawbacks for large-scale solar development include South Point (limited transmission capacity and distance from major load centers and potential opposition on environmental and cultural grounds), Ka'u Desert (competing land uses), and the Humuula saddle (endangered species and potential volcanic hazards). Large scale solar development has also been proposed at Keahole Point, currently the site of the Hawaii Natural Energy Laboratory Authority and its Gateway Center facility with 20 kW in solar.

Oahu's direct solar resource is concentrated on the leeward side of the island, primarily in areas of urban development. Relatively open spaces with good potential may exist at Pearl Harbor and the Lualualei Munitions Storage Area and Naval Communications Facility. Kahuku Point has a good solar resource, but its strong winds are also good for wind farms, although competing land uses may present challenges.

Southern Kauai also has good solar resources; however, there is a limited amount of land available for large-scale solar development in the Lihue-Poipu-Hanapepe area due to tourist development and urban housing.

Maui's solar resources are concentrated on the leeward side of the island and in the central isthmus, coinciding with tourist developments and agricultural lands.

Mauna Lani Resort has 80 kW of Solar Panels on Roof and over 500 kW total on property on Island of Hawaii. (Photo: PowerLight)

On Lanai, the solar resources are best on the southwestern portion of the island. Solar resources for Molokai are found on the western half of the island.

Figure 7 provides a map showing solar radiation on Hawaii. Solar maps of Kauai, Oahu, Molokai, Maui, and Hawaii, are available online at www.hawaii.gov/dbedt/info/energy/publications/solardata/. The estimated insolation isograms are shown overlaying relief maps of the islands so that physical features such as mountains can be referenced easily. Solar radiation is shown in terms of calories per square centimeters per day. An energy unit conversion table is provided to convert the contours to Btu per square foot and peak sun hours (or example, 600 Cal/cm^2 = 2200 Btu/sf = 7.0 peak sun hours), and major roads are shown. The maps are intended for general information and for use in sizing solar water heating systems, but may not be specific enough for more demanding applications such as detailed sizing of large-scale PV installations. The solar radiation data are available for download as a GIS layer at www.hawaii.gov/dbedt/gis/solrad.htm.

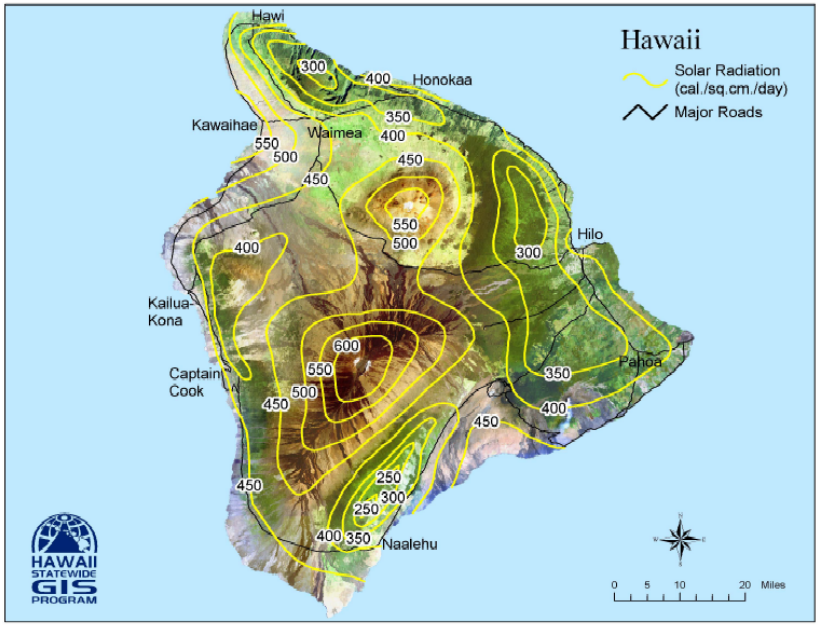

Figure 7. Solar Radiation on Hawaii

Installed and Planned Solar Energy Projects

Approximately 80,000 homes, multi-unit dwellings, and institutional facilities throughout the State of Hawaii use solar water heaters.

Although there are no large-scale photovoltaic or thermal-solar plants, several commercial solar projects are prominent in Hawaii, however the following list is by no means complete. The Mauna Lani Resort on the Island of Hawaii, for example, has invested in four on-site PV projects totaling about 500 kW. In 1998, the resort installed an 80 kW photovoltaic system on the main building roof, as well as a 110 kW system to power Mauna Lani's golf facility. The facilities are reportedly generating internal rates of return above 20%. The resort also deployed a fleet of solar-powered golf cars. In 2002, the Mauna Lani installed a tracking PV system composed of 24 rows of PV panels with a total capacity of 252 kW to power irrigation pumps.

Parker Ranch, also on the Island of Hawaii uses a 200 kW photovoltaic tracking system coupled with a 500 kW wind turbine system to provide power for water pumping.

Various projects being planned on Kauai total almost 500 kW.

In 2005, the largest federal solar PV installation in Hawaii, a 309 kW array was placed on the rooftop of an historic aircraft hanger at Ford Island in Pearl Harbor which opened in December 2006 as the Pacific Aviation Museum.

The state has significant potential for rooftop systems distributed generation and building-integrated PV that would not compete with agricultural or other land uses.

Prime Solar Development Areas

Table 8 is a compilation of information on promising large-scale solar project areas in Hawaii. Large solar projects are land intensive and are not necessarily compatible with other land uses. As a result, land availability is a major criterion in site identification. The solar resource is considered to be good on the leeward or southern and western sides of all the islands.

The table covers general location, resource information, and other observations. The resource column includes known, publicly available data as well as general comments on the known or suspected solar resource. DBEDT has collected the publicly available solar data and these data are available online at www.hawaii.gov/dbedt/info/energy/publications/solardata.

Table 8. Previously Identified Potential Solar Development Areas

General Location	Resource	Terrain	Other Comments
Island of Hawaii			
Keahole Point: North of Kona and south of the Waikoloa area	Global horizontal and diffuse horizontal solar radiation measured at the Natural Energy Lab of Hawaii Authority (NELHA), located in the Keahole Point area indicated that it is one of the best solar resources in Hawaii.	Fairly level and suited to all types of solar development.	Existing transmission lines in the vicinity; generation on west side of the island is desirable due to greater load growth.
North Kohala	Global horizontal, direct normal, and diffuse horizontal insolation data collected 9/93–8/94. Available from DBEDT (HES 1995).	Steep slopes preclude parabolic trough systems, but parabolic dish concentrating systems or photovoltaics are possible.	Transmission constraints in this region may limit project size.
Waikoloa: This broad region includes the Waikoloa general vicinity from Lanuipuaa to Kawaihae along the coast and inland toward Waimea	An excellent solar resource in the area has been documented by a number of data sources, including both global and direct radiation data. Data from several sites available for 9/93–8/94. Available from DBEDT (HES 1995).	Relatively flat near the coast with slopes as great as 5% further inland.	Existing transmission lines in the vicinity; generation on this side of the island is desirable due to load growth.
Kauai			
Barking Sands: Sufficient land is available in west Kauai in the vicinity of the Barking Sands Pacific Missile range	Global horizontal, direct normal, and diffuse horizontal insolation data collected 9/93–8/94. Available from DBEDT (HES 1995).	Area is a flat sedimentary plain with a high water table, which would have to be considered for any type of development.	Limited load growth in this area.
Lanai			
Manele Bay: Southeast region of the island	No data available but good resources likely.	The land is relatively flat and suitable for all types of solar development.	Limited load and transmission on Lanai but demand in this area is likely to grow due to resort locations and luxury home development.

Table 8. Previously Identified Potential Solar Development Areas			
General Location	**Resource**	**Terrain**	**Other Comments**
Maui			
Kahului Airport: Site covers the area to the south and east of the Kahului airport	Global horizontal insolation data collected 12/91-11/92. Available from DBEDT (HES 1995).	The land is relatively flat and suitable for all types of solar development.	Existing lines in the vicinity due to the proximity of the Kahului power plant.
Kihei: Area includes the lower southwest slopes of Haleakala, above the tourist developments of Kihei	Global horizontal, direct normal, and diffuse horizontal insolation data collected 9/93–8/94. Available from DBEDT (HES 1995)	The terrain has a much greater slope than Puunene (3%-6% at best, increasing to 10% or more to the south and farther inland) and the soil conditions are less favorable.	Transmission lines in vicinity and, due to projected load growth, this is a desirable location for generating capacity additions. Location of Research and Technology Center, PVUSA site.
Puunene: Old airport site near Puunene is located in the center of the Maui isthmus south of Kahului	Global horizontal, direct normal, and diffuse horizontal insolation data collected 9/93–8/94. Available from DBEDT (HES 1995)	The terrain and soil conditions are suitable for development.	There are existing transmission lines in the vicinity.
Molokai			
West Molokai	Global horizontal insolation data collected by HECO 6/92–11/93 and available from DBEDT (HES 1995).	The terrain and soil conditions are suitable for development.	Limited load and transmission.
Oahu			
North Ewa: This region includes former sugar fields north of Ewa, particularly those north of Highway H1, along Highway 750	Solar resource in this area is lower than in the coastal areas.	The majority of the terrain is gently sloped.	Inland areas may be more readily available, but displacement of agricultural land may be a concern.
Ewa Plain: Region includes land adjacent to the former NAS Barber's Point to the east over the entire Ewa Plain	No data available but good resource likely.	Flat	There are transmission lines in the vicinity. Much development is occurring in this area.

Table 8. Previously Identified Potential Solar Development Areas			
General Location	**Resource**	**Terrain**	**Other Comments**
Lualualei: A large flat valley situated to the west of the Honouliuli Mountains	No data available but good resource likely.	The land is relatively flat.	Several transmission lines exist in the valleys. Site of Naval Communications Center and Ammunition Storage.
West Loch of Pearl Harbor	Global horizontal, direct normal, and diffuse horizontal insolation data collected 9/93–8/94. Available from DBEDT (HES 1995).	The entire area is nearly level.	Site is centrally located to HECO's load and a number of transmission lines in the vicinity.

Programs to Stimulate Deployment of Solar Energy

Photovoltaic Projects for Public Schools

In 2006 the Hawaii State Legislature appropriated $5 million to the State Department of Education for a minimum of one PV project site at a public school on each of the islands of Oahu, Hawaii, and Kauai, and one public school within the County of Maui. To further reduce project costs, the project installation is to coincide with substantial roof repairs or roof replacement. In addition the projects are to use net energy metering to offset costs of the system; with payback within ¾ of useful system life, and, when advantageous, use energy-savings contracts such as third-party lease or purchase contracts to maximize savings. For details see Act 96, SLH 2006 at www.capitol.hawaii.gov/sessioncurrent/bills/HB2175_cd1_.htm.

Renewable Energy Income Tax Credits

Act 240, SLH 2006, set new amounts for renewable energy income tax credits for photovoltaic energy systems and solar thermal systems as shown in Table 9.

Table 9. Hawaii Renewable Energy Income Tax Credits for Solar Energy Systems

Facility	Maximum Tax Credit Percentage of Cost	Maximum Tax Credit for Solar Thermal	Maximum Tax Credit for Photovoltaic
Single-Family Residence	35%	$ 2,250	$ 5,000
Multi-Family Residenc	20%	$ 350	$ 350
Commercial	35%	$ 250,000	$ 500,000

Source: Act 240, SLH 2006
http://www.capitol.hawaii.gov/session2006/bills/SB2957_cd1_.htm

Additional Solar Information Resources

Data collected for Lihue, Honolulu, Kahuiui, and Hilo for flat plate, one-axis and two-axis tracking flat plate, and one- and two-axis tracking concentrating collectors are available online at: rredc.nrel.gov/solar/old_data/nsrdb/redbook/sum2/state.html.

Solar maps based on 2003 data are available at www.nrel.gov/gis/solar.html and a Solar Radiation Data Manual for Flat Plate and Concentrating Collectors can be found at http://rredc.nrel.gov/solar/pubs/redbook/.

NASA's renewable energy resource website contains data on meteorology and solar energy at http://eosweb.larc.nasa.gov/sse.

The National Climatic Data Center provides, for a fee, access to various climate data recorded from monitoring stations across the United States at www.ncdc.noaa.gov.

PV-DesignPro is a commercial product that includes extensive climate data tables at www.mauisolarsoftware.com.

Sandia National Laboratories Photovoltaic Systems Research and Development webpage, www.sandia.gov/pv, describes the efforts Sandia and its collaborative partners are undertaking to advance the use of photovoltaic technologies around the world.

Solar Reports and Publications

Photovoltaic Electricity in Hawaii (2006) DBEDT. The report discusses the feasibility of PV in Hawaii including historical cost trends and forecast of pricing. This report is available online at www.hawaii.gov/dbedt/info/energy/publications/pv-report06.pdf.

Solar Thermal Energy Fact Sheet (2005). Outlines the potential for solar thermal energy in Hawaii and provides links to further information and resources; available online at www.hawaii.gov/dbedt/info/energy/publications/solarnews05.pdf.

Solar Electric Generating Systems Assessment for Hawaii (1992) Kearney and Associates. The overall Solar Electric Generating System (SEGS) assessment evaluated the economic and technological potential of utility-scale solar thermal electric plants on the major islands, focusing on the issues of siting, design, utility requirements, operating characteristics, performance, and cost. Although this study addressed solar thermal trough technology as of 1992, it may still contain some useful information. The assessment was carried out by first examining the utility needs on the major islands through categorization of installed capacity, power purchase commitments, and resource planning. Next, an evaluation of SEGS technology for Hawaii yielded capital cost estimates for local conditions, as well as electrical generation performance projections based on a careful evaluation of potential solar resources on the major islands. In parallel, preferred SEGS sites were identified based on an appraisal of numerous siting issues. Lastly, a preliminary economics analysis of levelized electricity costs was conducted to compare Hawaii SEGS plants with conventional electric generation options. This report is online at www.hawaii.gov/dbedt/info/energy/publications/segs92.pdf/download.

An overview of Hawaii solar Information resources is available at www.hawaii.gov/dbedt/info/energy/renewable/solar/view.

Biomass, Biofuels and Biogas

Biomass encompasses all energy production using organic matter from trees, agricultural crops, and other plant material as well as biogas, primarily methane produced by the anaerobic digestion of organic materials, such as in landfill gas (LFG) systems and by anaerobic digesters using manure, farm wastes, or municipal sewage. Electricity and heat can be produced by burning solid biomass and by combustion of biomass derived gases or liquid fuels such as ethanol and biodiesel. Waste-to-energy plants, for example, burn municipal solid waste (MSW) to produce electricity.

While some types of dedicated biomass crops are grown specifically to be used as an energy source, waste from the production of a primary marketable product is often an economically viable energy source. In Hawaii, bagasse (sugarcane waste) has been the traditional biomass resource. However, the use of bagasse has decreased over the decades due to the declining sugar industry in Hawaii, which means new sources of biomass on Hawaii must be developed. Organizations such as the Hawaii Natural Energy Institute and Hawaii Agriculture Research Center are investigating replanting former sugar fields with energy crops. Banagrass, a fast-growing, herbaceous plant that reaches maturity in just seven months, is one such promising energy crop. According to the KIUC (2005), banagrass crops could theoretically supply all of Kauai's energy needs while utilizing only 20% of the land zoned Agricultural. Pineapples and forest plantings of mahogany and eucalyptus are also promising energy resources for Hawaii, as their growing stock and/or harvesting waste can be used.

The resource potential was inventoried in *Biomass and Bioenergy Resource Assessment for the State of Hawaii* (2002), prepared for DBEDT by the University of Hawaii, Hawaii Natural Energy Institute. Sources reviewed included domesticated livestock wastes, forest products residues, agricultural residues, and urban wastes. Agricultural wastes included those generated from sugar cane,

Unloading cane at the Hawaii Commercial and Sugar Puunene Mill, Maui. Photo by Steven Alber, DBEDT

pineapple, and macadamia nut culture and processing. The urban waste category was subdivided into four types: municipal solid waste, food waste, sewage sludge or biosolids, and waste greases. Tables of estimated annual resource amounts for each island are included in the report, available online at www.hawaii.gov/dbedt/info/energy/publications/biomass-assessment.pdf. Other than as noted, the information provided in the rest of this section has been extracted from this report.

Two sugar mills remain operating in the state, Hawaiian Commercial & Sugar Co.'s (HC&S) factory at Puunene on Maui, and the Gay and Robinson (G&R) factory located at Kaumakani on Kauai. In 2002, HC&S produced about 550,000 tons of bagasse at 50% moisture (~275,000 tons of fiber) and 80,000 tons of molasses, and G&R

produced about 147,000 tons of bagasse at 50% moisture (~74,000 tons of fiber) and 15,000 tons of molasses.

Pineapple harvested from roughly 19,000 acres across the state totaled 320,000 tons in 2002, of which 117,000 tons were sold as fresh fruit and the remainder was processed. Oahu pineapple production is sold primarily as fresh product. Fruit that are not suitable for fresh market sales are used to produce frozen product or concentrate and residues are disposed of by land application. Waste remaining in the field after the final harvest, about 10 dry tons/acre, is reincorporated into the soil. In some cases when the turn-around time between crop cycles is short, plants left in the field will be disked, allowed to dry, and then open field burned. Pineapple processing operations on Maui generate a residue byproduct (dewatered skins) that is currently provided to cattle producers for use as feed. This byproduct stream is estimated to be about 15,000 tons per year with estimated moisture content of 50%. This translates to a dry matter stream of about 7,500 tons available on an annual basis. Methods for handling in-field pineapple waste after final harvest in Maui are similar to those practiced on Oahu.

The Island of Hawaii currently has the largest forest plantings with commercial biomass potential in the state. The State of Hawaii has about 12,000 acres of timber resources in the Waiakea Timber Management Area (WTMA) on the Island of Hawaii containing more than ten different major tree species. Age and size of timber in the WTMA vary by species and location. The WTMA largely comprises non-native tree species, the exception being about 500 acres of ohia (*Metrosideros polymorpha*) and koa (*Acacia koa*). Roughly 33% of the WTMA is planted in five eucalyptus species with *Eucalyptus saligna* and *E. grandis* present in greatest abundance. The WTMA acreage is not in a contiguous land area but is contained within a rectangle roughly five miles wide by 12 miles long bounding the Stainback Highway leaving Hilo.

The State of Hawaii also has nearly 6,300 acres of non-native timber along the Hamakua Coast on the Island of Hawaii, extending from the Hamakua Forest Reserve, located roughly 8 miles west of Honokaa, to the Hilo Forest Reserve, located about 5 miles west of Hilo. This area measures about 40 miles from end to end. Plantings are not contiguous and are contained within 144 timber stands, some of which are located adjacent to one another. Roughly 5,300 acres of the Hamakua Coast timber land is planted in more than six eucalyptus species, with *Eucalyptus robusta* the largest single component occupying about 2,500 acres.

Private commercial forests totaling over 20,000 acres on the Big Island are slated for timber production rather than energy use. However, waste from sawmills or other processing could be used for energy generation and/ or biofuels production.

Macadamia nuts, grown and processed on the Island of Hawaii, have also been identified as a potential biomass resource. However, the harvested acreage of macadamia nuts decreased by about 1,500 acres between 1998 and 2002, and acreage is not expected to increase in the near future due to the cost and risk associated with establishing new orchards. Much of the existing acreage was planted during periods when tax incentives were available for orchard establishment.

The two plausible areas on the Island of Hawaii with enough resource of MSW to support waste-to-energy processing facilities are 1) the western coastal areas from South Kona to Kohala, and 2) the northeastern area of the island from Hilo and along the Hamakua Coast.

Collecting and combining the organic MSW generated in the eastern half of Kauai could potentially provide enough waste to be processed to make a waste-to-energy processing facility a viable option on Kauai. Additionally, using the boilers at the Kauai sugar facilities for the burning of waste products has been explored. Although this is technically viable, the State Department of Health has expressed concerns over the emissions. As an alternative, several plantations have examined the possibility of burning only green waste (not municipal solid waste), which should be considered biomass under their existing permits.

All regions of Maui, with the exception of the eastern portions of Haleakala (which are dominated by the National Park and several forest reserves), can be combined to merit the siting of a single waste-to-energy facility in the center of the island. Much of the MSW waste from these regions is currently hauled to a central landfill, so there would be no additional cost associated with transportation for a waste-to-energy conversion facility on Maui.

The MSW generated on both Molokai and Lanai is not enough to merit the construction of a waste-to-energy plant on those islands.

Figure 8 and Figure 9 show biomass and waste-to-energy resource information gathered from the biomass GIS viewer supported by the State's Office of Planning, available at: http://gis.hawaii.gov/website/biomass. Layers relevant to MSW and LFG are transfer stations, landfills, agricultural wastes, food wastes, fat/oil/grease (FOG) wastes, animal wastes, and waste water treatment plants.

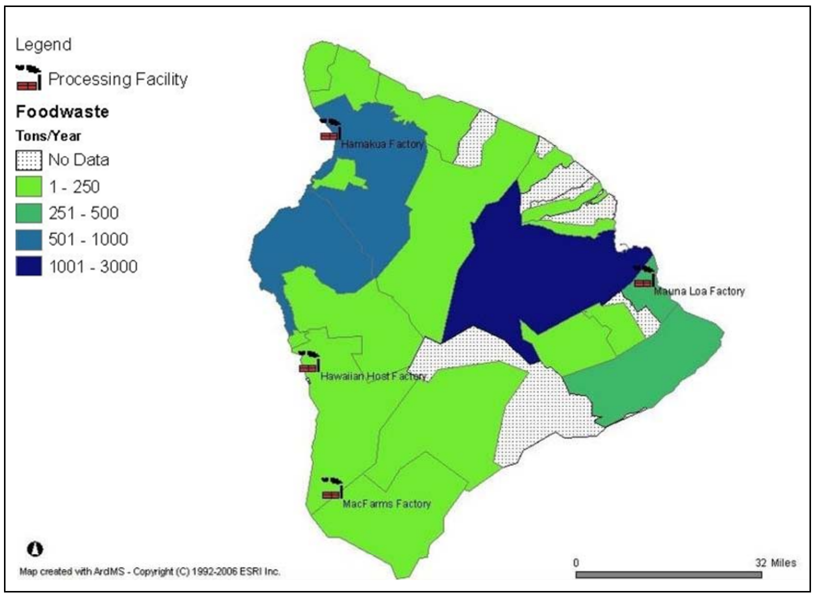

Figure 8. Biomass Food and Agricultural Waste Processing Facilities on the Island of Hawaii

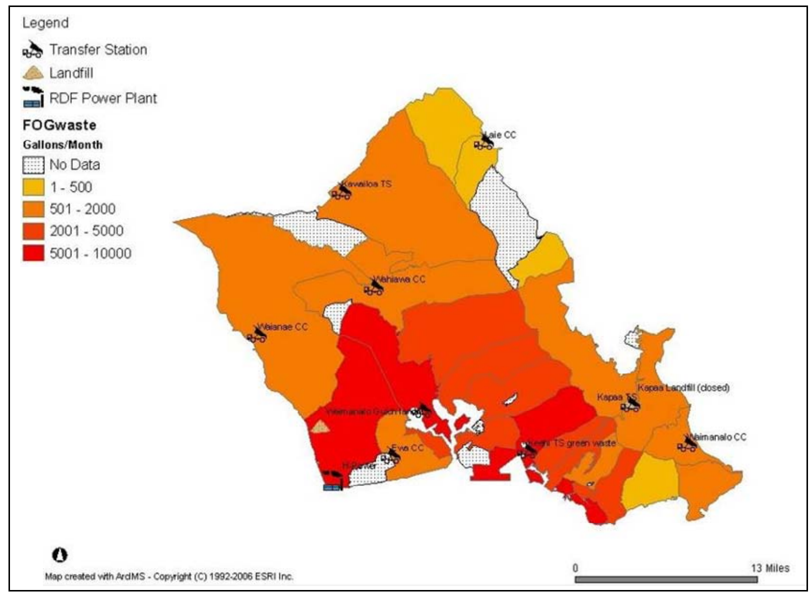

Figure 9. FOG Waste and Transfer Stations on Oahu

Installed Biomass and Waste-to-Energy Projects

Electricity from burning bagasse is currently used by the two remaining sugar factories in Hawaii (Hawaiian Commercial and Sugar (HC&S) on Maui and Gay & Robinson on Kauai) to meet steam and electricity needs, with excess electricity sold to the local utility. HC&S on Maui has produced an average of 244,019,000 kWh of electricity annually since 1990, selling an average of 39% of total production to MECO, or 9,133,000 kWh. The contract with MECO requires 12 MW of firm power out of a total steam unit capacity of 42 MW. To meet this need, HC&S supplements bagasse with oil or coal. The fossil fuels were used for an average of about 25% of electricity production annually since 1990. Gay and Robinson's steam unit has a 4 MW capacity. Since 1990, Gay and Robinson have produced an average of about 6,655,000 kWh annually. It sold an average of 34% of its bagasse-produced electricity, or 2,173,000 kWh annually, to KIUC. However, as of result of Hawaii's declining sugar industry, much of the former sugarcane land is used for other crops such as coffee, macadamia nuts, watermelon, and eucalyptus, or lies fallow.

A landfill gas-fueled generator operated on Oahu and a waste-to-energy project continues in operation there. Methane was captured from Oahu's Kapaa landfill and used to generate electricity from 1990 too 2002; however, the 3.2 MW facility ceased operations in 2002 following the combustion turbine. The landfill gas unit sold power to HECO and furnished exhaust heat to an adjacent quarry to dry sand. The HPower plant began burning municipal solid waste on Oahu and generating electricity for sale to HECO in 1990. While the principal purpose of HPower is to reduce the volume of MSW going to landfills, HPower sold an average of 334,425,000 kWh of electricity annually to HECO by processing and burning an average of 550,000 tons of waste per year. The HPower website provides an overview of the facility's operations, including a summary of public attitudes toward the project: www.honoluluhpower.com.

As a part of a recent request for proposals for renewable energy, KIUC awarded a contract for a 7.5 MW gasification/thermal oxidation facility on Kauai that will burn a dedicated fuel crop. The process involves slowly heating wood chips until volatile gases are released into an oxygen-deprived environment. The gas is then mixed with air for efficient combustion at high temperature. The proposed facility is considered a carbon neutral "closed loop" system as it will utilize a dedicated fuel crop of Eucalyptus and Albizia trees.

KIUC also awarded contracts to two other biomass-related projects: 1) one to develop a 5.3 MW waste-to-energy facility that will burn post-recycling waste, and 2) one to develop a 4.5 MW biomass facility that will utilize waste walnut shells as the primary fuel source. The walnut shells will be shipped from California.

Prime Biomass Development Areas

Table 10 and Table 11 list promising biomass and waste-to-energy sites identified in previous work. The biomass resource information is based on estimates developed and summarized in the HES 1995 Phase 1 report available from DBEDT at www.hawaii.gov/dbedt/info/energy/publications/index_html#1995. The resource estimates are based on potential, rather than existing, crop yields for fast-growing tree and grass species. Ownership and land use may also have changed and should be verified.

The 1995 HES study assumed that biomass processing facilities would be located at existing mill sites. Therefore, transmission lines to the sites were also assumed to be adequate. However, the unused sugar mills have mostly been dismantled and new equipment would likely be required. Some of the locations suggested in the 1995 HES study may no longer be available.

For MSW or LFG plants, sites would be located at or near existing landfills. Regions on the table refer to the waste source, in most cases.

Table 10. Previously Identified Potential Biomass Development Areas

General Location	Resource (Based on HES 1995 Phase1 Report)	Other Comments
Island of Hawaii		
Paauhau: Lands previously used for sugar by Hamakua Sugar Co.	Climate and soil conditions are particularly good for tree crops. Estimated tree crop production 144,000 dry ton/yr. Estimated grass crop production of 191,000 dry ton/yr.	
Pahala	This is the least productive tree crop land, but the most productive sugar crop land on Hawaii. Estimated tree crop production of 36,000 dry ton/yr. Estimated grass crop production of 123,000 dry ton/yr.	
Pepeeko	Have particularly favorable climatic and soil conditions for tree crops. Estimated tree crop production of 194,000 dry ton/yr. Estimated grass crop production of 121,000 dry ton/yr.	In the 1990's, the landowner was reportedly interested in developing 7,000 acres for a tree project to make particle board.
Kauai		
Eleele: former McBryde Sugar Co. land	Grass crops may be most suited for soil conditions. Estimated grass crop production of 93,000 dry ton/yr.	
Kaumakani: Olokele Sugar Company and Gay & Robinson land	Suited to tree and grass crops. Estimated tree crop production of 86,000 dry tons/yr (Olokele land only). Estimated grass crop production of 70,000 dry tons/yr.	
Former Kekaha Sugar land: Project area is located in the southwest region of Kauai near Kekaha	Grass crops may be most suited for local soil conditions. Estimated grass crop production of 99,000 dry ton/yr.	
Former Lihue Plantation land	Potential for grass and tree crops. Estimated tree crop production of 166,000 dry ton/yr. Estimated grass crop production of 119,000 dry ton/yr.	The site is also located near a deep water harbor, which may be beneficial for potential transportation fuel projects.
Former Olokele Sugar land: Located near Kaumakani on the southwest region of Kauai	Potential tree and grass crops.	Also located fairly close to a barge port at Port Allen.

Table 10. Previously Identified Potential Biomass Development Areas

General Location	Resource (Based on HES 1995 Phase1 Report)	Other Comments
Maui		
Former Lahaina Plantation land	Suitable for tree and grass crops. Estimated tree crop production of 50,000 dry ton/yr. Estimated grass crop production of 63,000 dry ton/yr.	Significant competing uses may exist for this land.
Paia: part of existing HC&S sugar plantation	Good potential for tree crops, some area for grass crops. Estimated tree crop production of 98,000 dry ton/yr. Estimated grass crop production of 519,000 dry tons/yr (combined with Puunene).	Approximately 12,000 hectares were considered for use with a processing facility located at the site of the closed mill.
Puunene: part of existing HC&S sugar plantation	Estimated tree crop production of 95,000 dry ton/yr. Estimated grass crop production of 519,000 dry tons/yr (combined with Paia).	Approximately 23,500 acres. Puunene Mill remains in operation, producing sugar.
Molokai		
Palaau: Central agricultural area	Suitable for tree and grass crops. Estimated tree crop production of 6,800 dry ton/yr. Estimated grass crop production of 99,000-132,000 dry ton/yr.	A processing facility would likely be located in the Palaau area near existing generation and transmission lines.
Oahu		
Former Waialua Sugar land	Potential for conversion to grass crops. Estimated grass crop production of 128,000 dry ton/yr.	Both the State of Hawaii and the City and County of Honolulu have expressed interest in maintaining green space, and a 4,000 acre biomass plantation was considered in this area.

Table 11. Previously Identified Potential MSW & LFG Development Areas

General Location	Facility Type	Estimated Resource/Size
Island of Hawaii: western coastal area	MSW facility	Approximately 71,500 dry tons/yr of organic waste
Island of Hawaii: northeastern area	MSW facility	Approximately 124,500 dry tons/yr of organic waste
Kauai: eastern half	MSW facility	Approximately 80,265 dry tons/yr of organic waste
Kauai: central	MSW facility: landfill processed over 200 tons/day or about 80,000 tons annually in 2005.	7.3 MW with a waste stream 300 tons/day (presumes approximately 100 tons/day purchased from other locations) was identified as an option by KIUC.
Kauai: landfill near Kekaha	LFG facility: Landfill given permission to operate through 2009. One cell capped, one cell still operating. No existing LFG or flaring facilities at landfill.	Estimated capacity of 0.7–1.0 MW. Recently analyzed gas samples indicated that the gas has potential to generate electricity and funding has been identified to design gas distribution and collection systems in cooperation with the Pacific Missile Range Facility.
Maui: central	MSW: Centrally locate a MSW facility next to existing landfill.	Amount of estimated waste was not reported.
Oahu: west quarter of the island	MSW facility	Approximately 317,500 dry tons/year of organic waste.
Oahu: Kapaa landfill	LFG facility	3.2 MW LFG project operated here from 1989 to 2002. The City and County of Honolulu have updated gas analyses and seek to resume power generation.

Additional Biomass Information Resources

The U.S. Environmental Protection Agency Landfill Methane Outreach Program's website contains information and data on landfills, energy project opportunities, and profiles of operating projects: www.epa.gov/lmop/proj/index.htm.

The *Update to the Integrated Solid Waste Management Plan for the County of Hawaii (2002)* is the first update to the County's Integrated Solid Waste Management Plan of 1993, which evaluates the remaining space in the county's landfills and plans for reducing waste, recycling, and creating energy from municipal solid waste and landfill gas. The report contains data on the amount of solid waste delivered to landfills each year, composition of the waste stream, and location of landfills and transfer stations. It is available online at www.hawaii-county.com/env_mng/iswmp_final_update.htm.

The *Hawaii 2000 Plan for Integrated Solid Waste Management* (2000), prepared by Belt Collins Hawaii and Rife Environmental, builds on the State's 1991 Integrated Solid Waste Management Plan and focuses on policy and sustainable plans. The report also contains some waste-stream data for the various landfills throughout the state and is available online at www.hawaii.gov/health/environmental/waste/sw/pdf/swmgmpln.pdf.

The Hawaii Agricultural Research Center (HARC) has published a summary of the state's sugar cane production from 1908-2003 online at: http://www.hawaiiag.org/harc/SugProd1908-2003.pdf.

Biodiesel Crop Implementation in Hawaii, a report prepared by HARC for the Hawaii Department of Agriculture, completed in October, 2006 is available through a link on line at: http://www.hawaiiag.org/hdoa/pdf/biodiesel%20report%20(revised).pdf

The Siting Evaluation for Biomass-Ethanol Production in Hawaii (1999) published by the Department of Biosystems Engineering, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, examines Oahu, Hawaii, Maui, and Kauai to identify the three best combinations of potential sites and crops to produce dedicated supplies of biomass for conversion to ethanol. Key technical and economic factors considered in the siting evaluation include land availability (zoning and use), land suitability (agronomic conditions), potential quantities and costs of producing biomass feedstocks, infrastructure (including water and power supplies), transportation, and potential bioresidues to supplement dedicated energy crops. This report is available at www.hawaii.gov/dbedt/ert/new-fuel/files/bioethanol/.

The mission of the Pacific Regional Biomass Energy Program, www.pacificbiomass.org, is to encourage the use and development of biomass energy technologies that are technically feasible and cost effective. The program works to provide technology transfer, remove barriers to biomass energy production and promote its benefits, and to provide information and technical assistance to improve the regional environment and economies.

The *Report to the Twenty-Third Legislature* (2005), State of Hawaii, Department of Health, Office of Solid Waste Management, summarizes disposal and dispersion amounts for each island for fiscal year 2005, as well as the rates of disposal and dispersion for fiscal years 2001-2005. The report is available at www.hawaii.gov/health/about/legrpts2006/finaloswmreport.pdf.

For the 1995 HES study, biomass resource data were assembled from field experiments in Hawaii conducted by investigators who have evaluated the performance of the referenced species and provenances in different environments. Information recorded for each experiment included growth age, mean diameter at breast height, mean height, initial planting density, survival rate, amount of nitrogen fertilizer applied, plot aspect (slope and direction), and elevation. Site variables included in the analysis were elevation, mean daily temperature, mean annual rainfall, mean daily solar radiation, soil nitrogen content, and soil Ph value. The referenced reports included:

Skolmen, R.G. *Performance of Australian Provenances of* Eucalyptus grandis *and* Eucalyptus saligna *in Hawaii*. Research Paper PSW-181. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California, 1986.

Whitesell, C.D., D.S. DeBell, T.H. Schubert, R.F. Strand, and T.B. Crabb. *Short-Rotation Management of* Eucalyptus*: Guidelines for Plantations in Hawaii*. Gen. Tech. Rep. PSW-GTR-137. Albany, California: Pacific South Research Station, Forest Service, U.S. Department of Agriculture, 1992.

Yost, R.S., D.S. DeBell, C.D. Whitesell, and S.C. Miyasaka. "Early growth and nutrient status of *Eucalyptus saligna* as affected by nitrogen and phosphorus fertilization." *Australian Forestry Research,* 17, 203-214, 1987.

BioEnergy Development Corporation. "*Eucalyptus* Plantations for Energy Production in Hawaii." Annual reports to the U.S. Department of Energy, 1980-1986.

Crabb, T.B. "*Eucalyptus* plantations for energy in Hawaii: ten years later." BioEnergy Development Corporation story, 1988.

DeBell, D.S., C.D. Whitesell, and T.H. Schubert. "Using N2-fixing albizia to increase growth of *Eucalyptus* plantations in Hawaii." *Forest Science*, 35, 64-75, 1989.

Dudley, N.S. *Performance and Management of Fast Growing Tropical Trees in Diverse Hawaii Environments*. MS thesis, Agronomy and Soil Science Department, University of Hawaii at Manoa, 1990.

Osgood, R.V. and N.S. Dudley. *Establishment of biomass-to-energy research facilities.* In Hawaii Integrated Biofuels Research Program – Phase III Annual Report. Subcontract No. XN-0-19164-1. Hawaii Natural Energy Institute, University of Hawaii at Manoa, 1990.

Geothermal

Exploration for geothermal energy in the state began in the 1960s. Geothermal resources with significant potential for production of electricity are located only on the Island of Hawaii and Maui. Currently, the state's only geothermal plant, operated by Puna Geothermal Venture, is located on the Island of Hawaii.

Figure 10 and Figure 11 present the geothermal resource maps for the Island of Hawaii and Maui taken from a 2005 study, *Assessment of Energy Reserves and Costs of Geothermal Resources in Hawaii*, conducted by GeothermEx, Inc., on behalf of DBEDT. The study reviews in detail seven geothermal resource areas (five on the Island of Hawaii and two on Maui) assesses their capacity for electrical generation, and estimates a realistic range of costs for future geothermal power plants in Hawaii. Some of the areas lie partially within national parks or state natural reserve areas, which may limit or prohibit their use for geothermal power production. This report is available online at www.hawaii.gov/dbedt/info/energy/publications/geothermal-assessment-05.pdf.

In addition, there are opportunities for direct use of geothermal heat for a variety of purposes. Many potential applications could offset energy use. These include fruit hydration, cold storage, aquaculture, greenhouse bottom heating, agricultural product processing, lumber drying, Pasteurization or sterilization of growing media, balneology (heated spa pools), heat pumps for heating and cooling, and a variety of other potential uses. These opportunities will not be detailed in this Catalog, but references will be cited at the end of this section.

Installed Geothermal Electricity Generation Projects

As of 2006, Puna Geothermal Venture (PGV) operates the only geothermal power plant in Hawaii. The plant began operation in 1993. The capacity of the plant is 30 MW, and it provided approximately 19.7% of the Island of Hawaii's electricity sold in

Puna Geothermal Venture on the Island of Hawaii. Photo: HECO.

2005. The only other geothermal power plant in Hawaii was a 3 MW publicly owned pilot project that operated during the 1980s.

Previously Identified Development Areas

Expanded production is possible at PGV and in other areas within the Island of Hawaii and Maui Geothermal Resource Subzones (discussed in Section 4 of the Catalog). Table 12 lists identified potential development areas on the Island of Hawaii and Maui based on the HES (1995) and GeothermEx, Inc. (2005) siting studies described above.

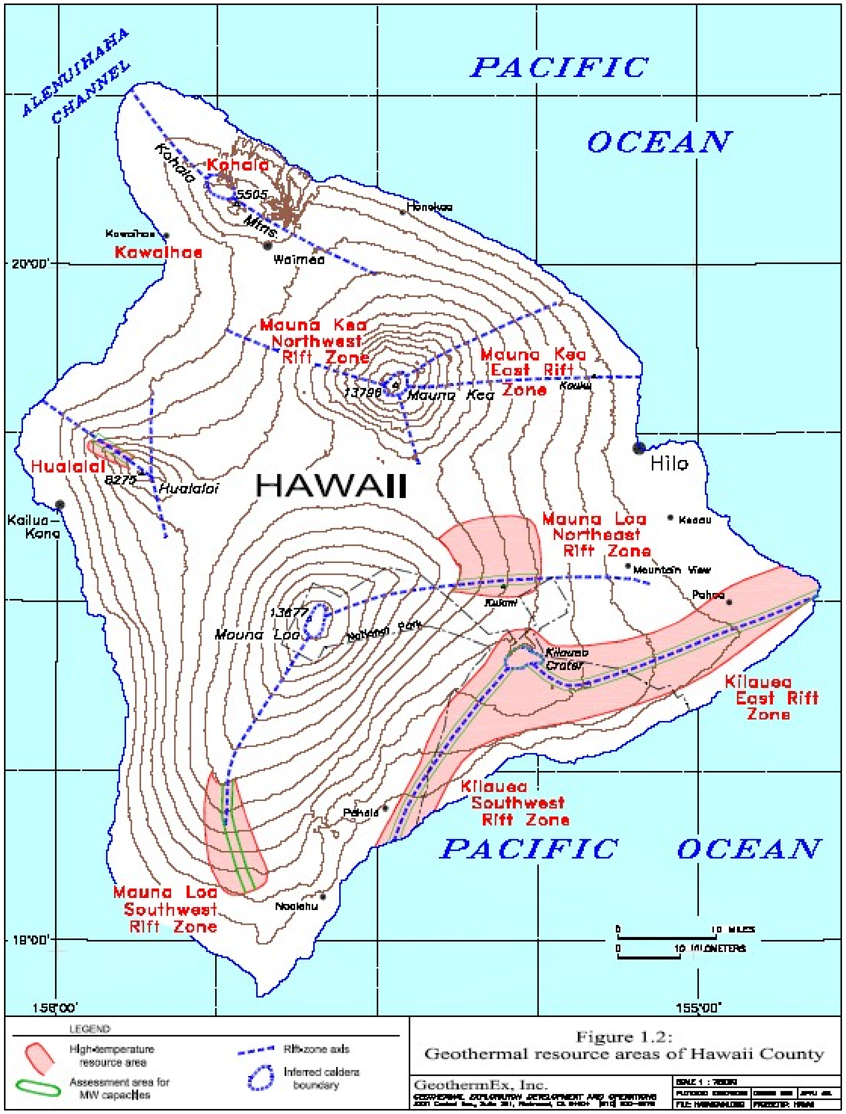

Figure 10. Geothermal Resources on the Island of Hawaii

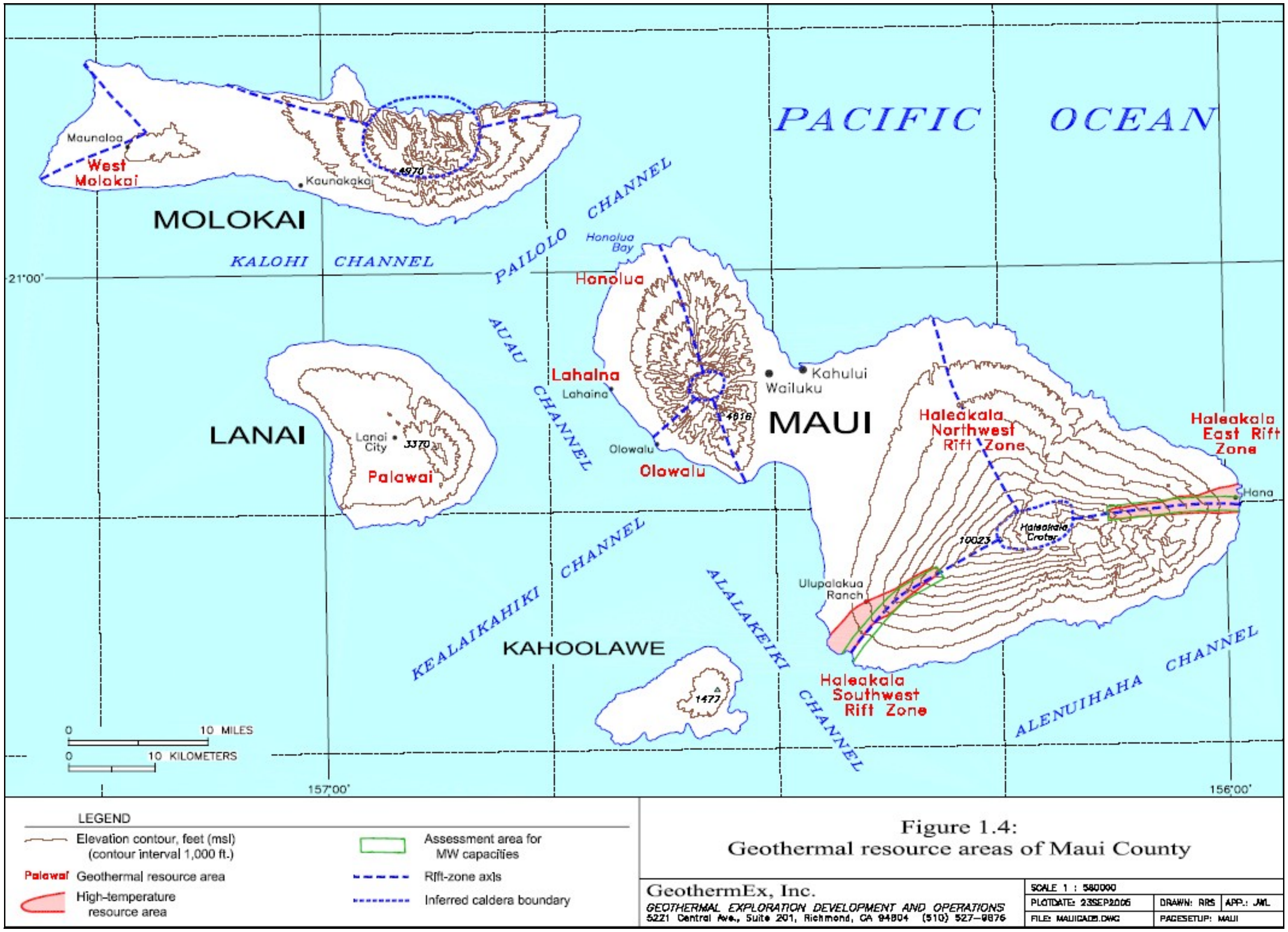

Figure 11. Geothermal Resources on Maui

Table 12. Previously Identified Potential Geothermal Development Areas for Electricity Generation

General Location	Resource	Other Comments
Island of Hawaii: Hualalai: Approximately 5-mile section of the northwestern rift zone	25-30 MW mean estimated reserves, estimated reservoir thickness 1,800–4,800 ft	Average temperature range: 257-500°F Rock porosity of 3%-7% Proximity to Kailua-Kona load center
Island of Hawaii: Kilauea East Rift Zone (KERZ): Extends approximately 32 miles from the summit of Kilauea Volcano to the sea	778 MW mean estimated reserves (lower portion 438 MW, excluding national parks and forest reserves), estimated reservoir thickness 4,450 ft for upper portion and 6,350 ft for lower portion.	Average temperature range: 580-650°F Rock porosity of 3%–7%
Island of Hawaii: Kilauea Southwest Rift Zone: Approximately 21 miles long	393 MW mean estimated reserves (lower portion is 193 MW excluding areas within the national park), estimated reservoir thickness 4,300 ft for upper portion and 6,200 ft for lower portion.	Average temperature range: 580-650°F Rock porosity of 3%-7%
Island of Hawaii: Mauna Loa Southwest Rift Zone: Resource area is approximately 11.5 miles long	125 MW mean estimated reserves, estimated average reservoir thickness 2,400–5,400 ft	Average temperature range: 400-650°F Rock porosity of 3%-7%
Island of Hawaii: Mauna Loa Northeast Rift Zone: Resource area is an 8.5-mile portion of the upper rift	75 MW mean estimated reserves, estimated reservoir thickness 1,600–4,600 ft	Average temperature range: 400-650°F Rock porosity of 3%-7%
Maui: Haleakala Southwest Rift Zone: Extends over 9 miles	69 MW mean estimated reserves, estimated reservoir thickness 3,500–6,500 ft	Average temperature range: 257-500°F Rock porosity of 3%-7% Closer in proximity to load centers in central and western Maui.
Maui: Haleakala East Rift Zone: Extends over 9 miles	70 MW mean estimated reserves; estimated reservoir thickness of 3,500–6,500 ft	Average temperature range: 257-500°F Rock porosity of 3%-7%

Additional Geothermal Information Resources

Geothermal Maps and Data

Idaho National Laboratory provides geothermal resource maps for Hawaii in PDF and JPEG formats as well as data for use in GIS software at http://geothermal.id.doe.gov/maps/index.shtml/.

Geothermal Reports and Studies

The DBEDT Geothermal Web Site at: http://www.hawaii.gov/dbedt/info/energy/renewable/geothermal has useful information and links studies and reports related to geothermal electricity generation and direct use of geothermal heat.

Update of the Statewide Geothermal Resource Assessment of Hawaii (2000) GeothermEx, Inc. A county-by-county assessment of areas with geothermal resource potential in the State of Hawaii updating two previous statewide assessments of geothermal resources issued in 1984 and 1992. The report is primarily intended to provide information on the potential for geothermal production, which is one of the considerations that Hawaii's Board of Land and Natural Resources must take into account in subzone designations. The report also discusses other planning considerations that have changed since 1992, including the State's Hawaii Energy Strategy program, forecasts of demand for electrical generation capacity, the possibility of direct use of geothermal resources, and the environmental impact of geothermal development. The report is available online at www.hawaii.gov/dbedt/info/energy/publications/georesource00.pdf

Development Activities for Geothermal Spas in the State of Hawaii (2000) GeothermEx, Inc. This report was prepared to assess opportunities for developing geothermal spas in Hawaii, and to provide a convenient summary of information for potential developers. It includes a discussion of the general characteristics of geothermal spas, identifies areas of the state with good prospects for spa development, discusses marketing considerations, reviews State of Hawaii regulations, and discusses significant economic factors. Available at: http://www.hawaii.gov/dbedt/info/energy/publications/geospa00.pdf

Prospective Direct Use Enterprises in Kapoho, Hawaii (2004) DBEDT. This is a paper presented at the 2004 Annual Meeting of the Geothermal Resources Council by Andrea T. Gill. It outlines opportunities for a variety of geothermal direct uses; discusses activities of Direct Use Working Group; describes available geothermal resources in Kapoho; Kapoho's current economic activities, and direct use opportunities, and the current regulatory environment. Available at: http://www.hawaii.gov/dbedt/info/energy/publications/GRC04-gill.pdf

A Regulatory Guide to Geothermal Direct Use Development: Hawaii (2004) Washington State University. A guide for developers of direct use geothermal projects to help them navigate the regulatory process is available at www.energy.wsu.edu/ftp-ep/pubs/renewables/hawaii.pdf.

Hydroelectricity

Hydropower plants have provided power for sugar mills and utilities in Hawaii for many decades, continuing to produce significant amounts of electricity on the islands of Kauai, Maui, and the Island of Hawaii. All of Hawaii's hydropower plants operate on "run-of-river" flows and do not have dams. Because Hawaii's stream flows vary considerably according to seasonal rainfall, hydropower is considered an "intermittent" resource on the islands.

Island of Hawaii: The hydro resource on the island is concentrated in the Kohala area and the Hamakua coast. HELCO has recently upgraded some of its hydroelectric facilities. A hydro project on this island on the Honolii Stream was denied a permit in the late 1980s due to concerns over potential effects on surfing conditions and aquatic life. This highlights a general hurdle for any new hydroelectric project on any of the islands.

Kauai: Additional resource potential exists in the river valleys of the northern and eastern portion of the island; however, all new proposed hydropower projects have faced local opposition.

Other islands: Several small hydro facilities operate in Maui. A recently refurbished hydroelectric facility was brought on line on Maui in September 2006. Molokai's main hydroelectric resource is the Halawa Stream. Oahu and Lanai have limited hydroelectric resources and no current hydroelectricity facilities.

Figure 12 contains watershed maps for Maui County produced by the Hawaii State Office of Planning. The State GIS program includes additional layers of information related to river and ditch locations, rainfall, and other data relevant to hydroelectric resources. Watershed information for other islands is available at http://www.hawaii.gov/dbedt/gis/wshed.htm.

Waiau Hydroelectric Plant, Wailuku River on the Island of Hawaii. Photo: HECO.

The USGS publishes real-time stream-flow data for 33 sites in Hawaii on the Island of Hawaii, Oahu, Kauai, and Maui at http://waterdata.usgs.gov/hi/nwis/current/?type-flow.

Installed and Pending Hydroelectric Projects

Hawaii's currently operating hydropower plants are listed in Table 13 based on information available in the HES and KIUC studies, as well as the HECO and KIUC websites. Small run-of-river hydroelectric plants are also operated by the Hawaii County Department of Water Supply, Wenko Energy Company, and various farms such as Hawi Ag & Energy and Hoowaiwai Farms on the Island of Hawaii. The Wailuku River Hydroelectric Power Company is the largest in the state at 11 MW.

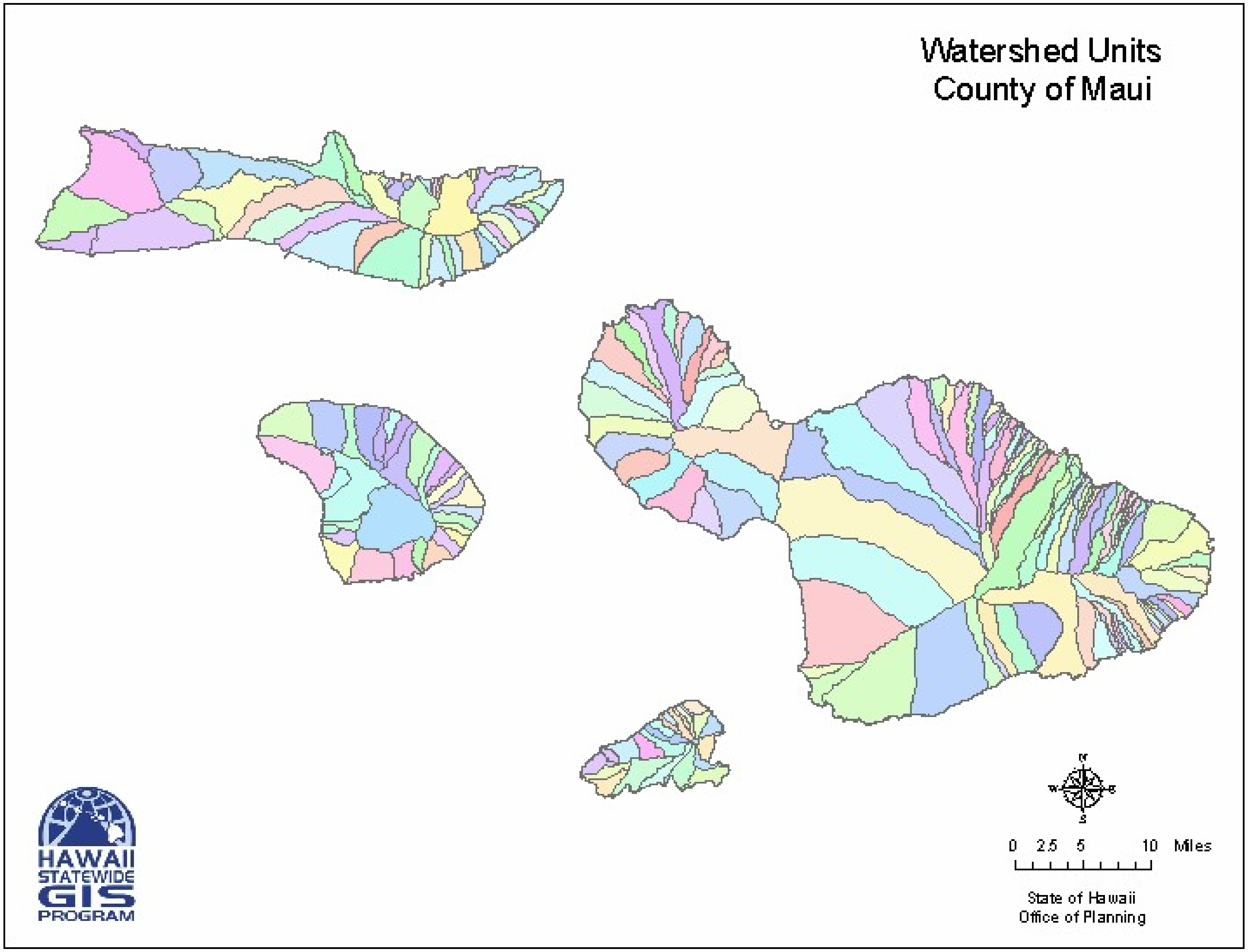

Figure 12. Watershed Map for Maui County

Table 13. Installed and Planned Hydroelectric Projects

Location	Project	Information
Island of Hawaii: Hilo	Wailuku River Hydroelectric Power Co.	11 MW, run-of-river; began operation 1993; located at the junction of the Wailuku River and the Kaloheahewa Stream.
Island of Hawaii: Hilo	Waiau Hydropower	1.15 MW, run-of-river; began operation 1920, upgraded 1947, penstock refurbished 1998; located on the Wailuku River.
Island of Hawaii: Hilo	Puueo Hydropower	2.5 MW, run-of-river, began operation 1910, upgraded 1941 and 2005; located on the Wailuku River downstream of the Waiau project.
Maui: Hamakua	HC&S Wailoa Ditch Hydropower	0.4 MW, run-of-river
Maui: Lahaina	Makila Hydro	0.5 MW, run-of-river; originally operated by Pioneer Mill Company but decommissioned in late 1990s when the mill closed. Upgraded and interconnected in September 2006.
Maui: Kaheka	HC&S Wailoa Ditch Hydropower	4.5 MW, run-of-river
Maui: Paia	HC&S Wailoa Ditch Hydropower	0.9 MW, run-of river
Maui: Ulupalakua Ranch	Auwahi	Pumped storage hydroelectric facility is under consideration in conjunction with a proposed 40 MW wind power plant.
Kauai	Waimea Mauka Hydro	1 MW, run-of-river; owned by State Agribusiness Development Corporation (ADC)
Kauai	Waiawa Hydro	0.5 MW, run-of-river; owned by ADC
Kauai	Lihue Lower	0.6 MW, run-of-river; owned by KIUC
Kauai	Lihue Upper	0.8 MW, run-of-river; constructed in 1931 by Lihue Plantation; now owned by KIUC.
Kauai	Wainiha Hydro	3.7 MW, run-of-river; developed by McBryde Sugar Company in 1906.
Kauai	Kalahea Hydro	1.0 MW, run-of-river; Kauai Coffee
Kauai	Waiahi Hydro	1.3 MW, run-of-river; Gay & Robinson

Potential Hydroelectric Development Areas

Given the permitting and public acceptance climate in Hawaii, any proposed hydroelectric project would need to be run-of-river.

Table 14 provides information for potential hydropower project areas identified in the studies listed at the beginning of this section.

Table 14. Previously Identified Potential Hydropower Development Areas

General Location	Information
Island of Hawaii: Kaula, Koholaele, and Luahala:	These three potential project areas are located on the Hamakua coast and they drain between the towns of Paauilo and Ookala. Water is used for irrigation.
Island of Hawaii: Kawainui:	6 MW potential. The Kawainui Stream is located on the Hamakua coast south of the Umauma project.
Island of Hawaii: Umauma:	15 MW potential. The Umauma Stream is located on the Hamakua coast and drains just north of Hakalau.
Kauai: Kitano-Waimea	4 MW potential; part of Kokee project that utilizes developed irrigation systems on the west side of Waimea Canyon.
Kauai: Puu Lua-Kitano	3 MW potential; part of Kokee project that utilizes developed irrigation systems on the west side of Waimea Canyon.
Kauai: Upper Lihue	Existing project; upgrade potential for additional 0.3 MW.
Kauai: Waimea Mauka	Existing project; upgrade potential for additional 2.9 MW.
Kauai: Wailua River	6.6 MW potential; some local opposition exists to previous development proposals.
Kauia: Wainiha	4 MW potential; upstream from existing Wainiha Hydro project.
Maui: Wailua Iki: Northeast region	3 MW potential. A hydro project was proposed for this area by Bonneville Pacific in the 1980s, but it was opposed on environmental grounds.

Additional Hydroelectric Information Resources

The general USGS website for Hawaii stream flow information is http://waterdata.usgs.gov/hi/nwis/rt.

Hydroelectric Power in Hawaii – A Reconnaissance Survey (1981) concluded that hydropower resources in the state are substantial, and they offer the potential for major increases in hydropower generating capacity of about 307 GWh per year. This represents about 28% of the present combined electricity needs of Kauai, Molokai, Maui, and the Island of Hawaii. Hydropower resources on Kauai were estimated to equal 72% of that island's electricity needs; on Molokai, 40%; on the Island of Hawaii, 20%, and on Maui, 18%. The island of Oahu, however, has only small hydropower resources and could only generate a negligible portion of its electricity needs from this energy source. The study did not address specific institutional barriers to development of the resource, so the generating capacities quoted should be regarded as the theoretical resource potential. This report is available www.hawaii.gov/dbedt/info/energy/publications/hydronews05.pdf.

U.S. Army Corps of Engineers (1981) *National Hydroelectric Power Resources Study, Volume XXIII, Regional Assessment: Alaska and Hawaii* documents the role of hydroelectric power in the region. The report presents information on potential projects to be considered for continued study in order to:

- Increase the energy self-sufficiency of the region;
- Assess the physical potential for increasing hydroelectric power capability and generation;
- Determine the potential for increasing hydroelectric generating capacity by development of new sites and by adding generating facilities to existing water resource projects;
- Assess the general environmental and socioeconomic impacts of hydroelectric power development; and
- Provide for maximum feasible utilization of the energy potential derived from the region's water resource.

This report is available at www.hawaii.gov/dbedt/info/energy/publications/hydro-ace-1981.pdf.

Ocean and Wave Energy

Almost all of the major U.S. experiments on ocean thermal energy conversion (OTEC) have taken place in Hawaii. The wide temperature difference between surface level ocean water and deep ocean water occurs relatively close to shore, making the Hawaiian Islands a highly desirable spot for OTEC development.

A wave energy device is also being tested in the waters off Oahu. The State of Hawaii has one of the world's best and most consistent wave regimes. The available annual wave energy resource off the northern shores of the Hawaiian Islands far exceeds the electricity demand of the islands. The primary sources of Hawaii's wave energy are seas built up by local trade winds, swell generated by storms in the north Pacific Ocean, and swell from similar storms in the southern hemisphere. High waves are also generated by tropical storms and Kona winds. While typically occurring only a few times per year at most, such waves present a significant hazard that must be considered in the design of any ocean energy plant.

The 20-fathom depth curve is often within 1 mile of the shore and usually is not far from the coral reefs that fringe much of the island coastline. The bottom generally pitches off rapidly to great depths from a narrow coastal shelf, and the few off-lying dangers usually are indicated by breakers or by a change in color of the water. Under normal conditions, the color of the water changes from a deep blue in the open ocean to blue-green between the 10- and 15-fathom curves. Bottom features become visible at 6-7 fathoms.

Wave power density along the 80-m depth contour typically averages 10-15 kW/m in Hawaii. Because the island shelves are so narrow, adjacent headlands or peninsulas can closely shelter even this outer shelf depth contour. At these areas (Kailua and Hilo, Oahu), the wave power density ranges from 7-9 kW/m at the 80-m depth contour. Figure 13 shows the 600-ft bathymetry contour map for the islands, defining the seaward boundary of Water Quality Classification zones.

Aerial View of the Ocean at Kahului, Maui. Source: NREL Photo Information Exchange. Photo by Warren Gretz.

Energy from the ocean currents may also have long-term potential in Hawaii. Although no significant work has been done in this area, small demonstration projects and initial assessment have been conducted in other areas of the United States. Additional investigation of ocean current energy for Hawaii is warranted as the technology progresses and matures.

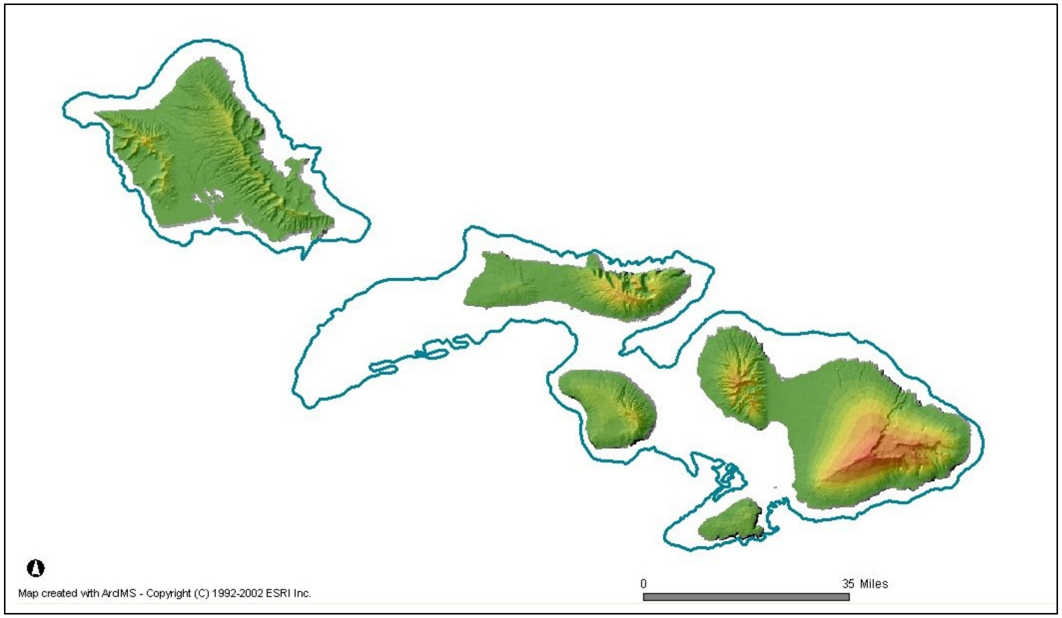

Figure 13. Bathymetry Contour (600-ft) for Oahu, Molokai, Lanai, and Maui

Installed Ocean and Wave Energy Projects

Ocean thermal and wave energy technology are still emerging technologies. Although no commercial ocean energy projects have been installed, a number of demonstration projects have been deployed and other projects have been proposed. Table 15 list several previous, on-going, and proposed demonstration projects in the state.

Table 15. Ocean Energy Projects

Location	Project	Information
Island of Hawaii: Keahole Point	OTEC demonstration	1979 closed-cycle, 18 kW
Island of Hawaii: Keahole Point	OTEC demonstration	1990s open-cycle, 103 kW
Island of Hawaii: Natural Energy Laboratory of Hawaii Authority in Kona	OTEC planned commercial project	1 MW, expected operation 2008
Oahu: Kaneohe Bay	Wave energy demonstration	20 kW installed June 2004, redeployed in 2005; in operation; planned expansion to 1 MW

Potential Ocean Energy Development Areas

The development areas shown in Table 16 were identified in the Hawaiian Energy Strategy report (1995 and 2000 and 2004 updates) and *E2I EPRI Survey and Characterization of Potential Offshore Wave Energy Sites in Hawaii* (2004) published by the Electric Power Research Institute, available at www.epri.com/oceanenergy/waveenergy.html#reports. Further details are included in the full reports.

Table 16. Previously Identified Potential Ocean Energy Development Areas

General Location	Resource	Other Comments
Island of Hawaii: Northern Coast	Significant wave resources identified.	Hilo Bay and Kawaihae were examined in the EPRI report but the existing port infrastructure to support device fabrication and assembly was questioned. The demand and transmission availability is greater on the west side than near Hilo. Development along the northeast coast may conflict with protected areas.
Island of Hawaii: Keahole: Proximity to the NELHA, which hosted an experimental OTEC facility.	OTEC: Keahole has proximity to deep ocean waters.	Demand and transmission availability is greater on this side of the island.
Island of Hawaii: Ka'u coast	OTEC: Area near South Point has proximity to deep ocean waters appropriate for OTEC.	Potential conflict with protected areas; transmission constraints may exist.
Kauai: Northern and southern coastline	OTEC: Deep water sites exist on the northern and southern coastlines.	The scenic beauty and protected resources of the northern part of the island will likely result in opposition to any development. Southern coastline sites are closer to demand but may have conflicts with tourism.
Kauai: Northern coastline	Significant wave resources identified.	The scenic beauty and protected resources of the northern part of the island will likely result in opposition to any land-based systems. Wave energy facilities may be more easily sited near Kapaa on the eastern coastline.
Kauai: Southern coastline	Significant wave resources identified.	Port of Nawiliwili (near Lihue) and Port Allen were examined in the EPRI report but the existing port infrastructure to support device fabrication and assembly was questioned.
Maui: Kahului Harbor: Northern coastline	Significant wave resources identified.	Kahului Harbor was examined in the EPRI report but the existing port infrastructure to support device fabrication and assembly was questioned.
Maui: Northeastern coastline	Significant wave resources identified.	Sites closer to Kahului are closer to demand and potentially less opposition.

Table 16. Previously Identified Potential Ocean Energy Development Areas

General Location	Resource	Other Comments
Maui: Northeast coast	OTEC: good near shore bathymetry near Hana.	Scenic beauty and protected areas may result in public opposition.
Oahu: Northeast coast	Significant wave resources identified between Kahuku Point and Makapu Point	High electrical demand, port infrastructure to support device fabrication and assembly. Humpback Natural Marine Sanctuary encompasses northern tip of Oahu (Haleiwa-Kaena) and southern coast (Diamond Head-Makapuu Point).
Oahu: Kahe Point:	OTEC: good near shore bathymetry resource	Favorable land use. Proximity to utility power plants and transmission.
Oahu: Makapuu Head/Waimanalo: North of the eastern tip of the island	Significant wave resources identified	Existing port infrastructure to support device fabrication and assembly. Near demand and transmission. Near area of demonstration project.

Additional Ocean Energy Information Resources

Resource Data

Maps, data, and general descriptions related to oceans, waves, and tides in Hawaii can be found at the following websites:

The following two companies operated wave gages in Hawaii:

- Scripps Institution of Oceanography http://nsdl.sdsc.edu
- Edward K. Noda and Associates www.ekna.hawaii.com

National Oceanic and Atmospheric Administration: portal to information on oceans, coasts, charting, and navigation, http://oceanservice.noaa.gov/welcome.html

National Geophysical Data Center:

- www.ngdc.noaa.gov/mgg/fliers/03mgg03 .html – hydrographic survey data, digital database available for purchase
- www.ngdc.noaa.gov/mgg/geodas/geodas.html – marine geophysics and Geophysical Data System (GEODAS), which is an interactive database management system
- www.ngdc.noaa.gov/mgg/bathymetry/relief.html – maps, topography, bathymetry, relief

United States Geological Survey:

- http://wrgis.wr.usgs.gov/dds/dds-55/pacmaps/hw_index.htm – Hawaiian Island shaded relief maps
- http://walrus.wr.usgs.gov/infobank/ – coastal and marine geology information bank
- http://geopubs.wr.usgs.gov/i-map.i2809.bathy.pdf – high-resolution bathymetry map of Hawaii

Monterey Bay Aquatic Research Institute: www.mbari.org/data/mapping/Hawaii – surveys of selected areas offshore of Niihau, Molokai, Maui, and the Island of Hawaii

Hawaii MR1 Seafloor Mapping System: Hawaii mapping research group based at the University of Hawaii www.soest.hawaii.edu/HMRG

U.S. Army Corps of Engineers (USACOE) Wave Data Sites provides wave height, period, and direction information, along with water depth for about 25 sites including Hawaii http://sandbar.wes.army.mil/

NOAA Coastal Services Center lists several sites that include water/wave/tide information on Hawaii. www.csc.noaa.gov/coos/hawaii.html

Coral Reef Ecosystem Investigation (CREI) Monitoring Network. NOAA program provides oceanographic and meteorological observations www.nmfs.hawaii.edu/cred

The Ocean Atlas of Hawaii Website contains information on marine climate, sea surface temperature and salinity, ocean currents, surface waves, and other related topics. http://radlab.soest.hawaii.edu/atlas/

Coastal utility grid and substation loads and capacities, and availability of onshore grid interconnection points: Hagerman (2004) Appendix C – coastal interconnection points.

Power delivery on Oahu: www.heco.com/images/pdf/PowerDelivery.pdf

The following resources provide maps and other information on competing uses of coastal areas in Hawaii:

Inventory Catalogue of Hawaii's Coral Reefs. Hawaii Coral Reef Initiative Computer Interactive Bibliography (HCRIB): http://home.hawaii.rr.com/cpie/CoralReefBib.html

NOAA – Office of Coast Survey:
nauticalcharts.noaa.gov/nsd/coastpilot1.htm
nauticalcharts.noaa.gov/nsd/coastpilot7.htm

National Marine Sanctuaries: www8.nos.noaa.gov/onms/park/Parks/?pID=18

Marine Protected Areas Inventory: mpa.gov/inventory/inventory.html

Fishing maps: www.ngdc.noaa.gov/mgg/bathymetry/maps/nos_intro.html

Location of Hawaiian ocean disposal sites: http://ngmdb.usgs.gov/ImageLibrary/

Military Warning Areas: www.globalsecurity.org/military/facilities/moa-midpac.htm

Commercial and Sport Fishing Grounds: www.hawaii.gov/dlnr/fish_regs/

Wildlife Refuges:
http://pacific.fws.gov/refuges/results.cfm (temporarily unavailable)

Environmentally Sensitive Areas:
http://home.hawaii.rr.com/cpie/CoralReefBib.html

Reports and Studies

Hagerman, G., Bedard, R., and Previsic, M. (2004) *E2I EPRI Survey and Characterization of Potential Offshore Wave Energy Sites in Hawaii*. This report identifies and characterizes potential offshore sites in Hawaii for a 1,500 MWh annual energy output (500 kW at 40% capacity factor) wave energy power plant feasibility demonstration and an envisioned 300,000 MWh per year (100 MW at 40% capacity factor) commercial plant. Sufficient data are provided to enable the E2I EPRI Wave Project Hawaii State Advisory Group to select a single site for a subsequent concept-level design, performance analysis, and cost estimate. Five Hawaiian coastal counties are potential sites for fabrication, construction, assembly, deployment, and servicing of offshore wave power plants. These counties and their harbors are characterized in this report. It provides many sources of data and information useful to developers of various wave and ocean energy technologies and is available at www.epri.com/oceanenergy/waveenergy.html#reports.

DBEDT (2002) *Feasibility of Developing Wave Power as a Renewable Energy Resource for Hawaii.* This report examines wave energy conversion systems (WECS), opines on the feasibility of Hawaii as a demonstration site, and outlines research and development goals. This report is available at www.hawaii.gov/dbedt/info/energy/publications/wavereport02.pdf.

Hagerman, G. (1992) *Wave Energy Resource and Economic Assessment for the State of Hawaii*. SEASUN Power Systems. This report was the first complete assessment of wave power as a potential energy source for Hawaii. As part of the study, a spectral formula was developed to represent the multi-component sea states that commonly occur in Hawaii and a refraction and shoaling analysis was undertaken to map the islands' wave energy resource. The wave energy conversion processes section discusses tapered channel, fixed oscillating water column, pivoting flap, heaving buoy, flexible bag, and submerged buoyant cylinder technologies. The economic assessment section discusses land- and caisson-based systems and offshore heaving buoy systems. Finally, the report presents conclusions and recommendations.

Electric Power Research Institute (2004) *Wave Energy in the U.S: Permitting and Jurisdictional Issues.* This report assesses the current regulations applicable to wave energy demonstration projects and explains the legal barriers and challenges associated with getting a test project approved. The report investigates installing one wave demonstration project in each of six states, including Hawaii. The report is available on the internet at: www.epri.com/attachments/297213_008_Wave_Permitting_Issues_Final.pdf.

Ocean Thermal Energy Conversion Fact Sheet (2005) published by DBEDT provides an overview of OTEC, projects and research conducted in Hawaii, and additional resources.
www.hawaii.gov/dbedt/info/energy/publications/otecnews05.pdf

Organizations

Natural Energy Laboratory of Hawaii Authority (NELHA) began as an OTEC research facility that has since branched out to encompass additional renewable energy technologies such as solar technologies.
www.nelha.org/

Hawaiian Islands Humpback Whale National Marine Sanctuary (HWNMS) http://hawaiihumpbackwhale.noaa.gov/

School of Ocean and Earth Science and Technology (SOEST), University of Hawaii SOEST undertakes research and education in all aspects of earth sciences. Research interests include: marine geophysics, the Kaneohe Bay project, the impact of both natural and human activities on the coastline of the Hawaiian Islands and a survey of Hawaiian submarine landslides (flank collapses). Its web site provides details of teaching, research, and data resources (Coupled Ocean Atmosphere Response Experiment (COARE)), Generic Mapping Tools (GMT), Marine Data Archives, Meteorology Weather Server, National Oceanographic Data Center (NODC), Ocean Atlas of Hawaii, Pacific El Nino Southern Oscillation Applications Center (ENSO), Pacific Regional Planetary Data Center (PRPDC), Shipboard ADCP Joint Archive, and University of Hawaii Sea Level Center). www.soest.hawaii.edu/

Possible federal permits affecting wave power devices have been outlined by the Ocean Renewable Energy Coalition. The information is posted as a PDF at http://www.oceanrenewable.com, listed in OREC's Library of Ocean Resources as "Table of Ocean Energy Regulations."

State of Hawaii permits relating to ocean energy development are summarized in the table, "Possible State of Hawaii Permits for Wave Energy." This summary, intended to provide guidance to potential wave power developers, completed October 2006, is on the DBEDT web site at:
http://www.hawaii.gov/dbedt/info/energy/publications/oceanpermitsummwithmapsOct2006.pdf

6. Sources for Further Information

The following agencies and organizations are active in Hawaii renewable energy development and can help answer questions about conducting business in Hawaii.

Utility Contacts

For information about power purchase contracts with Hawaii's utilities:

Dan Ching, HECO
Director of Power Purchase Division
(includes HECO, HELCO, and MECO)
Phone: (808) 543-4340
E-mail: daniel.ching@heco.com

Jeff Deren
Kauai Island Utility Cooperative
Phone: (808) 246-8287
E-mail: jderen@kiuc.coop

State Contacts

Department of Land and Natural Resources
Morris M. Atta
Special Projects Coordinator
DLNR, Land Div.
Phone: (808) 587-0410
Fax: (808) 587-0455
E-mail: morris.m.atta@hawaii.gov
www.hawaii.gov/dlnr/

Specific DLNR websites of interest include:

Division of Aquatic Resources at
www.hawaii.gov/dlnr/dar/index.html

Office of Conservation and Coastal Lands at
www.hawaii.gov/dlnr/occl/subzone.php

Maurice H. Kaya, Chief Technology Officer
State of Hawaii
Dept of Business, Economic Development & Tourism
Strategic Industries Division
P.O. Box 2359
Honolulu, Hawaii 96804
Phone: (808) 587-3812
Fax: (808) 586-2536
E-mail: mkaya@dbedt.hawaii.gov
www.hawaii.gov/dbedt/info/energy/

County Contacts

For information on County permit requirements:

City and County of Honolulu

Planning and Permitting Department
Henry Eng, Director
David K. Tanoue, Deputy
650 King St.
Honolulu, HI 98613
Phone: (808) 523-4432
Fax: (808) 527-6743
E-mail: info@honoluludpp.org
www.honoluludpp.org/

Permitting information related to land use policy and Special Management Areas (SMAs) is available from the department's website (above) by clicking on "Permitting Information" or going directly to http://www.honoluludpp.org/PermitInfo/.

County of Hawaii

Department of Planning
Aupuni Center, 101 Pauahi Street, Suite 3
Hilo, HI 96720
Phone: (808) 961-8288
Fax: (808) 961-8742
E-mail: planning@co.hawaii.hi.us
http://co.hawaii.hi.us/directory/dir_plan.htm

A useful explanation of the Hawaii Land Use Regulatory System (dated March 2006) is found at: http://co.hawaii.hi.us/planning/Land_Use_Regulatory_System.pdf or by clicking on "General Explanation of Hawaii Land Use System" at the Planning Department's webpage (URL given above).

County of Kauai

Department of Planning
4444 Rice Street, Suite 473
Lihue, HI 96766
Phone: (808) 241-6677
Fax: (808) 241-6699
http://www.kauai.gov/planning

County of Maui

Department of Planning
200 South High Street
Wailuku, HI 96793
Phone: (808) 244-7735
E-mail: planning@mauicounty.gov
URL http://www.co.maui.hi.us/departments/Planning

Permit applications, including those for the Special Management Area, are available online at http://www.co.maui.hi.us/departments/Planning/planningforms.htm

County Energy Offices

For information on energy activities on each island:

County of Hawaii
Bob Arrigoni
Energy Engineer
25 Aupuni St. Rm 109
Hilo, HI 96720
Phone: (808) 327-3664
www.hawaii-county.com/directory/dir_research.htm

County of Maui Energy Office
Kal Kobayashi
Energy Coordinator
County of Maui Energy Office
200 South High Street, Room 604
Wailuku, Maui, HI 96793
Phone: (808) 270-7832
kal.kobayashi@co.maui.hi.us
Note: The County of Maui encompasses the islands of Kahoolawe, Lanai, Maui, and Molokai.

Kauai Office of Economic Development
Glenn Sato
Energy Coordinator
Kauai Office of Economic Development
4444 Rice St., Suite 200
Lihue, Kauai, HI 96766-1300
Phone (808) 241-6393
E-mail: gsato@kauai.gov
E-mail: glenn@kauaied.org

Other Contacts

Hawaii Renewable Energy Alliance
Warren Bollmeier
46-040 Konane Place #3816
Kaneohe, Oahu, HI 96744
Phone: (808) 247-7753
E-mail: wsb@lava.net

Hawaii Natural Energy Institute
www.hnei.hawaii.edu
Located on the campus of the University of Hawaii, the Institute's responsibilities include conducting and supporting basic research; managing research facilities and laboratories; demonstrating the applications of its work; and investigating the social, environmental, and financial impact of energy- and marine-related activities.

Natural Energy Laboratory of Hawaii Authority (NELHA)
www.nelha.org NELHA began as an OTEC research facility that has since branched out to encompass additional renewable energy technologies such as solar technologies. The organization focuses on economic development of Hawaii.

Renewable Resource Data Center
http://rredc.nrel.gov/
this website contains information and data on biomass, geothermal, solar, and wind energy technologies. It also contains dynamic maps and GIS data.