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Hawaii Energy Strategy - Project 3

Renewable Energy Resource Assessment And Development Program

November 1995

prepared for:

State of Hawaii
Department of Business, Economic Development & Tourism
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RENEWABLE ENERGY RESOURCE ASSESSMENT PLAN

Phase 1: Renewable Energy Resource Assessment And Development Program

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LIST OF ACRONYMS

ACI	Augustyn & Company, Inc.
ALISH	Agricultural Lands of Importance to the State of Hawaii
DBEDT	Department of Business, Economic Development & Tourism
DNI	direct normal (broad band) irradiance
DVS	data verification system
GHI	global horizontal (broad band) irradiance
HELCO	Hawaiian Electric Light Company
HES	Hawaii Energy Strategy
HNEI	Hawaii Natural Energy Institute
HNRIS	Hawaii Natural Resources Information System
HSPA	Hawaiian Sugar Planters' Association
NELH	Natural Energy Laboratory of Hawaii
NREL	National Renewable Energy Laboratory
OTEC	ocean thermal energy conversion
PICHTR	Pacific International Center for High Technology Research
RLA	RLA Consulting
RSR	rotating shadow band radiometer
SRIC	short-rotation intensive culture
WMO	World Meteorological Organization

SUMMARY

RLA Consulting (RLA) has been retained by the State of Hawaii Department of Business Economic Development & Tourism (DBEDT) to conduct a Renewable Energy Resource Assessment and Development Program. This report summarizes the results of Phase 1 of this program. The purpose of Phase 1, entitled Development of a Renewable Energy Resource Assessment Plan, is to better define the most promising potential renewable energy projects and to establish the most suitable locations for project development in the state. In addition, a monitoring plan was developed to obtain additional wind and solar resource data in areas with development potential. Future work on this program will include the collection of the data, the quantification of the costs and annual energy output for these projects, and the development of resource supply curves.

In order to identify possible renewable energy project sites with significant development potential, RLA determined constraints and requirements for renewable energy projects for six different renewable energy resources: wind, solar, biomass, hydro, wave, and ocean thermal. Consideration of geothermal energy was added to this investigation under a separate contract with DBEDT. A screening process was used to identify the most promising project locations based on factors such as resource intensity, land availability, environmental constraints, utility interconnection, zoning, and public acceptance. For this phase of the project, the emphasis for project identification was on utility-scale, grid-connected renewable energy projects, however, potential applications for small, distributed uses were identified where appropriate.

Hawaii has an abundance of renewable energy resources. For most renewable energy technologies, a sufficient resource exists on each island to warrant consideration of an energy project. With few exceptions, issues other than the resource were the determining factor in identifying projects with development potential. Because these other issues (e.g., public acceptance, land availability, land ownership, utility grid size) are subject to change over time, the project lists identified in this report should be considered in the context of existing conditions. Future developments may either enhance or decrease the opportunities for renewable energy projects. For example, utility interconnection of the islands or significant load growth could increase potential project sizes. However, the land uses associated with the reasons for load growth may conflict with potential renewable energy projects. Other examples of factors that could impact project development in the future include the changing nature of the military presence, which may free up large parcels of land, and increased public acceptance of the visual impact of wind turbines.

Despite the limitations noted below, a significant number of renewable energy projects that have substantial development potential were identified on each island. As a result of the elimination process, the projects represent realistic opportunities for developing renewable energy in the State of Hawaii. These projects would result in renewable energy making a significant contribution to Hawaii's energy mix. Quantifying this contribution is the subject of future phases of this program.

A review of the existing wind and solar data and the potential project sites that were identified for these technologies was the basis for developing a monitoring plan for additional data collection. Existing, high-quality data sets and monitoring stations were identified and these data will be incorporated into the monitoring program. Ten additional wind monitoring stations and six additional solar monitoring stations were recommended.

One of the largest factors in eliminating potential projects from consideration is the availability of land without conflicting or competing land uses. Only on Hawaii and the lightly populated islands of Lanai and Molokai were sites identified in which the potential for competing land uses were not considered to be an issue. This is not to say that development of projects is impossible on the other islands; only that the demand for land is high and the impact of an energy project on a particular site will be weighed against other potential uses for that land as well as any potential impacts on activities on

surrounding lands. Primary competing land uses include urban expansion (primarily housing and light industry), conservation, and agriculture.

The total generating capacity of the utility grid on each island also limits potential development, particularly of intermittent generating technologies. Changes in the operating characteristics of the utilities, incorporation of energy storage, widespread use of electric vehicles, or island interconnection are factors that could alter this condition. As a result, projects were not eliminated from consideration on this basis. Nonetheless, the small grid capacity and growth projections of Lanai and Molokai preclude large-scale project development in the near future. Small-scale renewable energy projects (less than 50 kW) are best suited for these islands, either through demand side or dispersed generation applications. Given the relatively high energy cost on these islands, small-scale renewable energy projects should be economical on a widespread basis and have the potential to make a significant contribution to reducing petroleum dependency. On the other islands, utility-scale projects (1 MW or larger) are technically feasible. Although small-scale renewable energy applications are also likely to be possible at many locations on these islands, larger projects will make a more substantial contribution.

On Maui, Kauai, and Oahu, the majority of the mountainous land is restricted to either parks or forest reserves and the coastlines are either restricted from development or developed for urban uses or tourism. As a result, land-intensive energy projects are difficult to site in areas other than those used for agricultural purposes. Most of the biomass energy crop projects assume replacement of existing crops with an energy crop. A number of the wind and solar project sites also displace existing agricultural land uses. The likelihood of these projects depends heavily on market trends for the existing crops, particularly sugar. The sugar industry in Hawaii is on the decline with only a few economically viable plantations remaining. In many cases, land previously devoted to the production of sugarcane in these areas could be used for biomass crops or other renewable technologies.

The OTEC, hydro, and wave energy projects may require the use of highly protected shorelines or streams. Public acceptance of these projects is expected to be a major hurdle. However, the public perception of all energy projects is difficult to quantify and subject to change. For example, in Europe, wind turbines are often sited in highly populated areas that might be considered unacceptable in the United States. As these technologies become more common, public perception of their use, particularly in terms of visual impacts, are likely to change.

SECTION 1. INTRODUCTION

RLA Consulting (RLA) has been retained by the State of Hawaii Department of Business, Economic Development & Tourism (DBEDT) to conduct a Renewable Energy Resource Assessment and Development Program. This three-phase program is part of the Hawaii Energy Strategy (HES), which is a multi-faceted program intended to produce an integrated energy strategy for the State of Hawaii. The purpose of Phase 1 of our project, Development of a Renewable Energy Resource Assessment Plan, is to better define the most promising potential renewable energy projects and to establish the most suitable locations for project development in the state. In order to accomplish this goal, RLA has identified constraints and requirements for renewable energy projects from six different renewable energy resources: wind, solar, biomass, hydro, wave, and ocean thermal. These criteria were applied to areas with sufficient resource for commercial development and the results of Phase 1 are lists of projects with the most promising development potential for each of the technologies under consideration. Consideration of geothermal energy was added to this investigation under a separate contract with DBEDT. In addition to the project lists, a monitoring plan was developed with recommended locations and a data collection methodology for obtaining additional wind and solar data. This report summarizes the results of Phase 1.

The technologies considered in this project were prioritized based on their commercial status and their ability to contribute to Hawaii's energy mix. For this phase of the project, the emphasis for project identification was on utility-scale, grid-connected renewable energy projects. Although small-scale, demand-side or small-scale, dispersed-generation projects have the potential to reduce Hawaii's oil dependency, their application is more difficult to quantify because, in most cases, their adoption is based on subjective factors such as a home owner's willingness to invest capital. Also, the factors that were considered in this phase of the program, such as land availability, environmental constraints, utility interconnection, and zoning, do not generally apply to small-scale systems. However, these types of projects are included in the project list and their contribution and economics will be considered in greater depth in later phases of the program.

Biomass and hydroelectric are the most commercially proven renewable technologies available in Hawaii and, in relation to their potential, both of these have been used extensively in the state. In this project, the investigation of additional hydroelectric projects was fairly limited because most potential hydroelectric projects have been previously identified. In addition, the majority of these potential projects are fairly limited in capacity and the likelihood of implementing new hydroelectric projects is small due to strong opposition to new projects, a complex permitting process, and a pending policy from the State of Hawaii Office of State Planning regarding the classification of Hawaii's streams and development guidelines.

Biomass, through the sugar industry in Hawaii, has been used extensively throughout the state. Additional opportunities exist in terms of both the use of crops for energy (for either transportation fuels or conversion to electricity) and municipal solid waste. For biomass, Phase 1 of this project concentrated on identifying the most appropriate energy crop for the available agricultural lands and quantifying the municipal solid waste.

Wind and solar technologies have more recently entered the commercial market and, although the power output from these sources tends to be intermittent, their energy potential remains largely untapped. Additional resource assessment work for these technologies offers the most potential for promoting an increase in the use of renewable energy sources in Hawaii. As a result, identifying appropriate development sites for large-scale projects for these technologies and recommending additional monitoring sites was a primary objective of Phase 1. Of these technologies, wind is the most mature, and a number of wind energy developers have proposed projects in the state.

Wave and ocean thermal energy projects have considerable long-term potential in Hawaii, and several sites have been identified as potential locations for commercial projects. The commercial status of these technologies, however, does not at this time justify an in-depth analysis of potential sites at this time beyond what has already been completed. As the technology matures for these resources, the requirements and constraints may change considerably. For example, more than fifty different wave energy conversion technologies have been developed worldwide in the last decade [1]. Evaluating the range of possibilities for the most economical and best-suited technologies for potential project sites is beyond the scope of this report. For ocean thermal projects, future commercial power plants are envisioned as floating facilities. The impacts and requirements of such systems are not yet clearly defined. As a result, limited effort was expended on siting these technologies in Phase 1. A more in-depth analysis of their status and economics will be completed in future phases.

Geothermal energy conversion from high-temperature, water dominated resource areas is a mature technology that has been commercially deployed since the 1960's. Significant technological advances are not expected by the year 2005. One geothermal project has recently been installed on the Island of Hawaii in the Kilauea east rift zone. Even though this project was the subject of intense public opposition, further expansion in this same area is expected to be the most likely option for increased geothermal power development in the state.

The following sections describe the screening process that was used to identify the most promising renewable energy project sites, present the project lists for each technology, and describe the monitoring plan for additional wind and solar resource data.

SECTION 2. IDENTIFICATION OF POTENTIAL RENEWABLE ENERGY PROJECT SITES

APPROACH AND METHODOLOGY

For each of the technologies under consideration, a potential project list was developed based on an elimination process of the available land on each of the six major Hawaiian islands: Hawaii, Maui, Molokai, Lanai, Oahu, and Kauai. For each island, geographic areas were identified in which resource potential exists and an in-depth screening process was conducted that included consideration of factors such as land ownership, zoning, current and planned land uses, technology-specific development requirements, utility access and impact, environmental constraints, and public acceptance. For wind and solar, the project lists are the basis for the recommended monitoring plan. The following sections describe the approach and methodology for identifying project sites in terms of the screening factors.

RESOURCE INTENSITY

For each technology, geographic areas were identified in which sufficient resource was believed to exist to permit commercial development. The resource intensity was based on the best data currently available, either direct measurements or extrapolations from related information.

Wind: The areas with significant wind energy resource were identified based on a previously created wind atlas for the state of Hawaii, miscellaneous wind studies throughout the state, and RLA's independent assessment of the available data [2,3,4]. In addition, RLA considered areas in which data were not currently available but for which a significant resource was suspected to exist based on terrain or vegetation indicators. Field visits were performed at all potential resource areas to verify the available information and note any factors that could not be identified otherwise. The average annual wind speed, the wind speed distribution, and the height at which prior measurements were taken were considered in determining whether the resource was sufficient for commercial development.

Solar: Areas with significant solar resources were identified based on previously created solar maps (based primarily on Hawaiian Sugar Planters' Association data), miscellaneous solar studies throughout the state, RLA's independent assessment of the available data, and the average direct insolation estimated for various locations as compared to a long-range station at the University of Hawaii at Manoa [5]. All potential resource areas were surveyed during the field visits. Both global and direct (when available) solar radiation data were considered in determining whether the resource was sufficient for commercial development.

Biomass: Two types of biomass energy crops were considered: short-rotation intensive culture (SRIC) tropical hardwoods, and grass crops specifically cultivated as a biomass feed stock. The biomass energy wood crop resource was estimated as expected crop yields per acre of land based on information from the Hawaii Natural Resources Information System (HNRIS) geographical information system and database developed by the University of Hawaii. HNRIS considers both the soil and climatic conditions for individual areas to determine the crop yields for specific plant species.

For grass crops, the assumption was made that each existing sugar plantation has the potential to be the location of a grass crop plantation because it is highly likely that an energy grass crop would be closely related to sugar itself. However, short rotation grass crops, tailored specifically for biomass to energy conversion are easier to grow, easier to harvest, and less cumbersome to transport than sugarcane. The potential for grass crop yield was estimated based on historical yields from the plantations as published by the HSPA. These estimates are expected to be conservative since the species of grass crop for biomass-to-energy facilities will be chosen to optimize yield at the specific location while sugarcane is grown specifically for sugar production. In comparison to sugarcane, grass crops can be expected to be faster growing, yield a higher dry weight per acre, have a lower water content, and be easier to harvest and process for use. While the yield was based on actual sugarcane production values, costs for the installation and operation of the facilities was based on techniques consistent with biomass-for-energy facilities. On Molokai, a banagrass crop was considered. Information on areas of planted cane and annual harvested amounts of cane were derived from the 1992 Hawaiian Sugar Manual. The information concerning a banagrass crop on Molokai was obtained from Dr. Charles Kinoshita, Hawaii Natural Energy Institute.

Another biomass technology considered was converting organic waste material to energy and other by-products. The resource for organic waste conversion is the number of tons of organic waste per year for each island or region within an island. Data for organic waste generation were obtained from a recent survey of Hawaii's organic waste potential that was completed for DBEDT by Unisyn [6]. The energy end-product that is converted from trees, grass, or organic waste can be methanol, ethanol, or electricity.

Hydroelectric: All significant streams and irrigation ditches were considered as potential hydroelectric resources. The resource potential for this technology is based on the available head and annual stream flow. Areas with development potential were determined based on a survey of all of Hawaii's streams and rivers [7]; however, due to the difficulty involved in siting hydroelectric facilities, locations investigated were restricted to existing or currently proposed hydroelectric facilities [8,9]. Final project sites were selected based on the predicted availability of projects to successfully complete the permitting and public review process.

Wave and OTEC: The wave and OTEC resource for tropical islands, and specifically for the Hawaiian islands, has been shown to be virtually boundless [1]. The ocean thermal resource is determined largely by the bathymetry of the ocean. The wave resource is defined by the wave spectrum for various sea states. Because of the commercial status of these technologies, however, project locations were restricted to the locations that have been previously evaluated and for which detailed resource information is currently available. No attempts were made to evaluate the resource availability in areas that have not been previously identified. For OTEC, the resource locations and potential project sites were based on work conducted by the Natural Energy Laboratory of Hawaii (NELH) and Pacific International Center for High Technology Research (PICHTR) [10,11]. For wave energy, the resource locations and potential project sites were based on a wave resource assessment study conducted for DBEDT [1].

Geothermal: The Hawaiian islands are a volcanic island chain. The volcanic structures are an obvious source of a potential geothermal resource. While the theoretical geothermal energy potential in the state is virtually boundless, development of such projects has been seen to be highly controversial. Since future development is likely to be highly restricted, this study examines the cost and performance of new power generation projects in the immediate vicinity of the recently completed facility in the Kilauea east rift zone. The most accessible, developable geothermal resource in the Kilauea east rift zone is characteristically a high-temperature, water-dominated resource area.

LAND ZONING

The state-wide system of land zoning defines land districts as either Urban, Rural, Agricultural, or Conservation. The Conservation district is further divided into areas of General, Limited, Special, and Protective subzones. In addition, land may be further classified as Shoreline. Each of these land use districts and subzones has specific regulations as to the allowable land uses and permitting processes required. The boundaries of these districts are periodically reviewed by the Office of State Planning. While modifications are made, the practices allow the state to encourage or discourage various land use activities (i.e., policy or legislative changes could make more land available for renewable energy development). Projects were identified in this report based on current zoning practices. Preliminary zoning maps were developed based on the information contained in the HNRIS database (see Appendix A). Within each of the geographic areas identified as having resource potential, RLA verified the land zoning and determined the subzoning based on the most currently available zoning maps from the State Land Use Commission and the Conservation Division of the Department of Land and Natural Resources. For each of the resources under consideration, land was screened as follows:

Wind: There is specific wording that allows wind energy development in Agricultural districts, and it is anticipated that, barring conflicting land uses, wind energy will be allowable in Rural districts. It is foreseeable that, with some permitting requirements, wind energy projects could be developed in Conservation district subzones labeled as Resource and General. The elimination criteria used for wind sites are as follows:

1. No reasonable expectation of development in the following areas: Urban districts and Protective, Limited, and Special Conservation subzones. (Note: Federal land used for military purposes that is zoned urban was not necessarily eliminated if current land use practices permit consideration of a renewable energy project.)

2. Limited expectations of development in the following areas: Resource and General Conservation subzones.

3. No explicit land use barriers in the following areas: Rural and Agricultural districts.

Solar: It is anticipated that, barring conflicting land uses, solar energy will be allowable in Rural districts. It is foreseeable that solar energy projects could be developed in Agricultural districts where the soil is of quality C, D, E, or U, (denotes limited value for agricultural use) according to the ALISH system (Agricultural Lands of Importance to the State of Hawaii) and in Conservation district subzones labeled as Resource and General. The elimination criteria used for utility-scale solar sites are:

1. No reasonable expectation of development in the following areas: Urban districts and Protective, Limited, and Special Conservation subzones. (Note: Federal land used for military purposes that is zoned urban was not necessarily eliminated if current land use practices permit consideration of a renewable energy project.)

2. Limited expectations of development in the following areas: Resource and General Conservation subzones, and Agricultural Districts (where soil is of C, D, E, or U quality; county approval is required).

3. No explicit land use barriers in the following areas: Rural Districts.

Biomass: Only land currently zoned for Agriculture was considered for energy crop biomass projects. The land availability scheme for biomass plantations was previously developed for use with the HNRIS system [12]. For this study, land availability was considered for the islands of Kauai, Maui, Molokai, and Hawaii. Previous work completed by the University of Hawaii indicated that land-intensive biomass energy crop projects would not be feasible on Oahu or Lanai. On Lanai, the sole landowner has committed to tourist development and, mainly because of the limited demand, is not interested in pursuing an energy crop project However, both the state and the city and county of Honolulu are interested in maintaining parts of Oahu as a green belt. One potential biomass project was considered on Oahu based on the conversion of current sugarcane land.

For organic solid waste projects, land zoning was not considered as a criteria for eliminating projects. The land requirements for a processing facility will by driven by the location of the waste stream, and, with the exception of protected conservation land, this type of facility should be feasible to site within any zoning category.

Hydro, Wave, OTEC, and Geothermal: These technologies are not land intensive, and, as such, were not eliminated based on land zoning. The majority of the 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. Due to the value of this limited land resource, sites for further development are likely to be based on the existing land use conditions rather than zoning. The proposed location for geothermal projects is in a previously identified resource area where recent project construction was completed but not with extensive public opposition. Further development anywhere in the state will likely be difficult.

TERRAIN SUITABILITY

In general, flat land is acceptable for any type of project. For the land-based technologies considered, steep, mountainous terrain or heavily forested land is not suitable for project development. In the state of Hawaii, most such lands were eliminated from consideration by zoning for resource conservation. Technology-specific terrain requirements such as slope, vegetation cover, and soil characteristics were also used as a criteria for eliminating land areas and ranking project sites. Wind energy and parabolic dish solar energy projects are relatively insensitive to topography, although the terrain may dictate the spacing and configuration of the array of units. Solar troughs and photovoltaic arrays for utility-scale applications require a more even slope. For example, solar trough technology, in particular, is best suited to areas where the slope is less than 2% and the soil is easily manipulated. As a result, a number of sites that were eliminated for solar trough projects were retained as potential solar dish or photovoltaic projects. Biomass crop requirements are similar to the existing needs of sugar cane or pineapple fields. Because these agricultural lands were the only lands considered for this study, terrain suitability is likely.

COMPETING USES

Land uses competing with energy production in Hawaii are related to the state's major industries: agriculture and tourism. The value of an energy project on a plot of land must be compared to the value of using that plot of land for a different purpose, without the energy project. The more significant land uses competing with energy projects include housing projects, golf courses, tourist resorts, crop farming, grazing, and environmental preservation. In some cases, land may be used for multiple purposes.

Current and planned land use were determined through a field survey of the areas under consideration, discussions with landowners, and discussions with county land use planners. In addition, the State Land Use District Boundary Review reports for each island were reviewed to determine the rationale for any potential land use re-classifications that may be undertaken by the State [13-16]. During the field surveys, areas with obvious land use conflicts (i.e., existing development) were eliminated from further consideration. The majority of the large landowners in Hawaii have long-term land use plans for the lands under their control. These plans, along with any long-term leases or contracts that impact land use, were discussed with the landowners as well as their positions on utilizing portions of their land for renewable energy projects. A common concern among landowners is the impact of a renewable energy project on other existing or planned uses on their land, particularly tourist development and agriculture. Another factor to consider when replacing existing agricultural crops with more industrial energy projects is that the agricultural lands are often seen as a buffer between urban developments and areas used for conservation and tourism.

The majority of the land that is preserved or protected (i.e., parks, watershed, forest reserves) was previously eliminated based on zoning. Land slated for urban expansion or tourism development was also eliminated. The following additional factors were considered in screening for conflicting uses:

Wind: Wind energy is compatible with some agricultural uses, as the turbine foundations physically occupy only a small fraction of the project site's land area. The area between turbine foundations can be used for grazing or, in some cases, crop cultivation. In Hawaii, the two main crops, sugar, and pineapples, require harvesting techniques that are not as compatible with wind energy as other crops.

Although there is no technical incompatibility with these crops, landowners and plantation managers have indicated that it may make their typical harvesting techniques more difficult. With pineapple cultivation, for example, the periodic location of wind turbine towers would greatly interfere with the equipment used to harvest pineapples. The burning of cane fields may also affect wind turbines. For this study, these agricultural uses were not used to eliminate land from consideration as a wind energy site unless the landowner specifically indicated that he would not consider development on his land. Grazing is considered to be compatible with wind energy, as has been demonstrated on the island of Hawaii, at the Lalamilo Wells wind farm and at Kahua Ranch.

Solar: Due to its land-intensive nature, solar energy conversion is incompatible with most agricultural uses. For this reason, the siting of solar projects was generally not considered in Agricultural districts that have been identified as either prime or unique according to the ALISH system unless the landowner indicated that he would consider the replacement of agricultural crops with this type of project if it was economical. Dish sterling solar technology may be compatible with some grazing uses. In addition, the reflection from solar projects must be considered so that it does not interfere with nearby activities.

Biomass: The ability to cultivate energy crops will depend largely on factors in the sugar, pineapple, and oil markets. For our study, a methodology was used to evaluate land availability based on five levels of land use sensitivity [12]. Only land parcels in the two most favorable land use sensitivity classes were considered to be available for SRIC tropical hardwood plantations. Land suitability for energy crops was based on both the intrinsic and manageable environmental conditions of a given site required by a given species to achieve a targeted yield. To determine land suitability for Eucalyptus grandis, eucalyptus saligna, and Leucaena leucocephala production, data were assembled from field experiments in Hawaii conducted by other investigators who are evaluating the performance of these species and provenances in different environments [17-24]. 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. These site data were obtained from the literature or from the HNRIS database. For this study, all agricultural land with sufficient soil and climate conditions to provide acceptable yields were considered even if they were currently planted in another crop.

Energy production from organic waste conversion, as mentioned before, is not land intensive and is not impacted in the same way by competing land uses. Depending on the technology employed, the by-products from organic waste processing may be desirable for agricultural purposes, and it may be favorable to locate waste-to-energy conversion facilities near to, or on, agricultural lands. For organic waste, the transportation of the waste is a primary consideration and facilities are likely to be centrally located near existing landfills to take advantage of the in-place waste disposal transportation strategies.

Hydro: The main land use competing with hydroelectric power development is environmental preservation and recreation. Public opposition due to these factors is a primary consideration for siting hydro projects, and the primary factor likely to limit additional development in the State.

Wave and OTEC: The primary conflicting land use for any land-based ocean energy system is access and use of the shoreline. The island shorelines are very valuable for tourism, and other ocean access activities, so the future development of wave and OTEC projects is likely to meet with considerable competition unless there is a drastic increase in both the economic value of energy production and the cost of generating electricity from other sources.

The sites evaluated for this study were chosen to minimize any competing land use issues. As the technologies become more cost effective, competing land use issues will demand more attention.

Geothermal: The Kilauea east rift zone is zoned for both agricultural and conservation uses in about equal proportions. There is a minor amount of urban land. The conservation land occurs mainly on the western portion of the Kilauea east rift zone including the Hawaii Volcanoes National Park. The middle and lower zones are predominantly agricultural. Ownership in the lower zone includes state land and others. This area has been designated as a Geothermal Resource Subzone.

OWNER ACCEPTANCE

After completing the above screening process, the possibility of a renewable energy project was discussed with the landowners of the remaining land areas that appeared suitable. Preliminary land ownership classifications were determined from HNRIS (see Appendix B). Tax key maps were reviewed for more detailed information regarding ownership of specific parcels and private land. The likelihood of the development of an energy project is highly dependent on how it will affect the overall income of the landowner. The cost of producing energy must not only compare favorably with the price obtained by selling the energy, the project will also be judged on how it affects the profitability of planned land uses of surrounding lands. Most power generating technologies are not directly compatible with tourism activities due to visual impact, so a landowner that plans a vacation resort will often be unwilling to site an energy project on nearby land. In the case of wind energy, several landowners have even indicated the concern that the visible presence of wind turbines may imply that their resort is frequently windy and deter patrons from making reservations. In contrast, other landowners planning resort areas have even expressed an interest in renewable energy projects on their property as part of diversified land use planning. In some areas, renewable energy projects have been viewed as tourist *attractions*.

Because of the concerns of private landowners, state or federal lands are particularly attractive as potential energy project sites. Although these lands generally require more permitting for project development, lower lease rates may make these lands more favorable than private lands.

UTILITY ACCESS AND IMPACT

Access to utility transmission lines was the primary factor considered in project identification relating to utilities. Because it is possible to upgrade or build new lines to support projects, sites were not necessarily eliminated due to limited transmission access or distance from transmission lines. In some cases, however, it became obvious that the expense and/or distance of new transmission lines was excessive and these projects were dropped from further consideration.

Appendix C includes more specific information on the Hawaiian utilities, including transmission and distribution maps, expansion plans, and diurnal and seasonal load characteristics.

In addition to electrical access, solar thermal projects require a method of disposing of a certain amount of waste water. Biomass conversion technologies have considerably more waste removal requirements than other renewable energy technologies; however, in many instances the "waste" byproducts may be desirable for agricultural uses and can be sold to various plantations, thus eliminating the need for utility waste removal.

ENVIRONMENTAL AND CULTURAL SENSITIVITY

All project sites were screened for the preexistence of biologically significant native ecosystems or rare species, as well as the existence of culturally valuable archaeological sites, and the ability to mitigate against disturbances in areas that were found to be sensitive. While this screening was conducted by persons closely associated with the Nature Conservancy and familiar with the Hawaiian islands, it does not preclude the possibility that some biological or cultural feature may have been overlooked. Any site for proposed development in the state of Hawaii should be carefully surveyed and evaluated before proposed construction.

In this study, the environmental and cultural sensitivity of a potential project site was used to rank the projects. In most cases with environmental or cultural conflicts, possible resolution can be obtained by restricting the project size or using appropriate siting practices.

For the environmental screening, information regarding rare and endangered species was acquired from various sources, including the Hawaii Environmental Risk Ranking Project's Risks to Ecosystems Report, the Nature Conservancy's Hawaii Heritage Program, U.S. Fish and Wildlife Service Hawaiian Waterbird Recovery Plan, the Hawaii Stream Assessment, and personal communications with scientists and land managers in Hawaii.

For the purposes of this report, cultural resources include prehistoric, historic, and modern elements. In Hawaii, prehistoric resources generally refer to those prior to the arrival of Captain James Cook in 1778. Elements of historic, or post-contact, resources include sites listed on the State of National Register of Historic Places, historic districts, fishponds, and a variety of site types studied by the Historic Preservation Division under the Department of Land and Natural Resources. The Historic Preservation Division provided broad scale information on historic and archaeological data. Since the 1970s, archaeological surveys have been included for developments due to the Historic Preservation Law. Information from these surveys, as well as information from the University of Hawaii and Bishop Museum projects, was also incorporated into the report to the extent possible. Appendix D contains an environmental and cultural rating for each of the proposed project sites.

PUBLIC ACCEPTANCE

The assessment of public acceptance is critical in all modern development projects as public opposition to development puts significant investments at risk. While it was not appropriate in this preliminary stage to address the public at large about concerns relating to the development of specific renewable energy projects, during site visits, every attempt was made to identify areas of concern at the local level. This was accomplished through interviews with landowners, public planning officials, and past experience from renewable energy developers in Hawaii. Specific areas of concern are addressed in the following discussion of project sites.

RENEWABLE ENERGY PROJECT LISTS FOR THE STATE OF HAWAII

Following the completion of the above screening processes, project lists were developed for each technology. In the following sections, the project lists are presented by island. An overall map that identifies the general location of the potential project sites is provided for each island. A brief discussion of each project site by resource type follows. Site-specific maps are included in Appendixes E through J. Note that the majority of the site-specific maps identify representative, not exact, locations for projects and are provided for general information only. Exact project siting will require negotiations with the landowner and detailed resource assessment. Although in some cases, the landowner has identified a specific parcel for development, the majority of the landowners have only agreed to consider the possibility of a project and have not agreed to the specific sites located on the maps. The location of biomass energy crop projects are based on mill site locations, although the land area of the projects would extend well beyond the mill site location.

For the sake of completeness, small-scale applications are listed on each of the project lists for wind and solar. There are a number of small-scale, demand-side or small-scale, dispersed-generation projects utilizing wind and solar energy that are suitable for wide-spread use in Hawaii; however, identifying specific sites for these applications is beyond the scope of this work. In future phases of this program, the economics for these types of systems will be evaluated for representative locations that could be replicated throughout the islands. The lack of detailed discussion of these applications should not diminish their potential value. Small-scale, demand-side or small-scale, dispersed-generation projects utilizing solar and wind include applications such as solar hot water heating, solar or wind for off-grid remote applications, wind water pumping, distributed photovoltaics to defer utility upgrades, and solar desalination.

HAWAII

There is abundant available land on the island of Hawaii suitable for renewable energy development projects. Vast areas with sufficient resources for development were identified after the screening process. The value of renewable energy projects is more limited by the size of the utility load than by any other factor. The peak annual load in 1992 was 150 megawatts. Due to the large amount of available land, and the low apparent demand, only a limited number of possible projects were chosen for discussion and they do not necessarily represent the island's maximum potential. In addition, broader regions were identified for project sites rather than specific locations and a number of potential projects may be possible within a given region. The projects that are presented, however, are representative of the types of projects that are available to develop in Hawaii and it is anticipated that additional projects that may be proposed would have similar characteristics. Potential renewable energy projects for each technology are discussed in the following section. The general locations of potential project sites are shown in Figure 1.

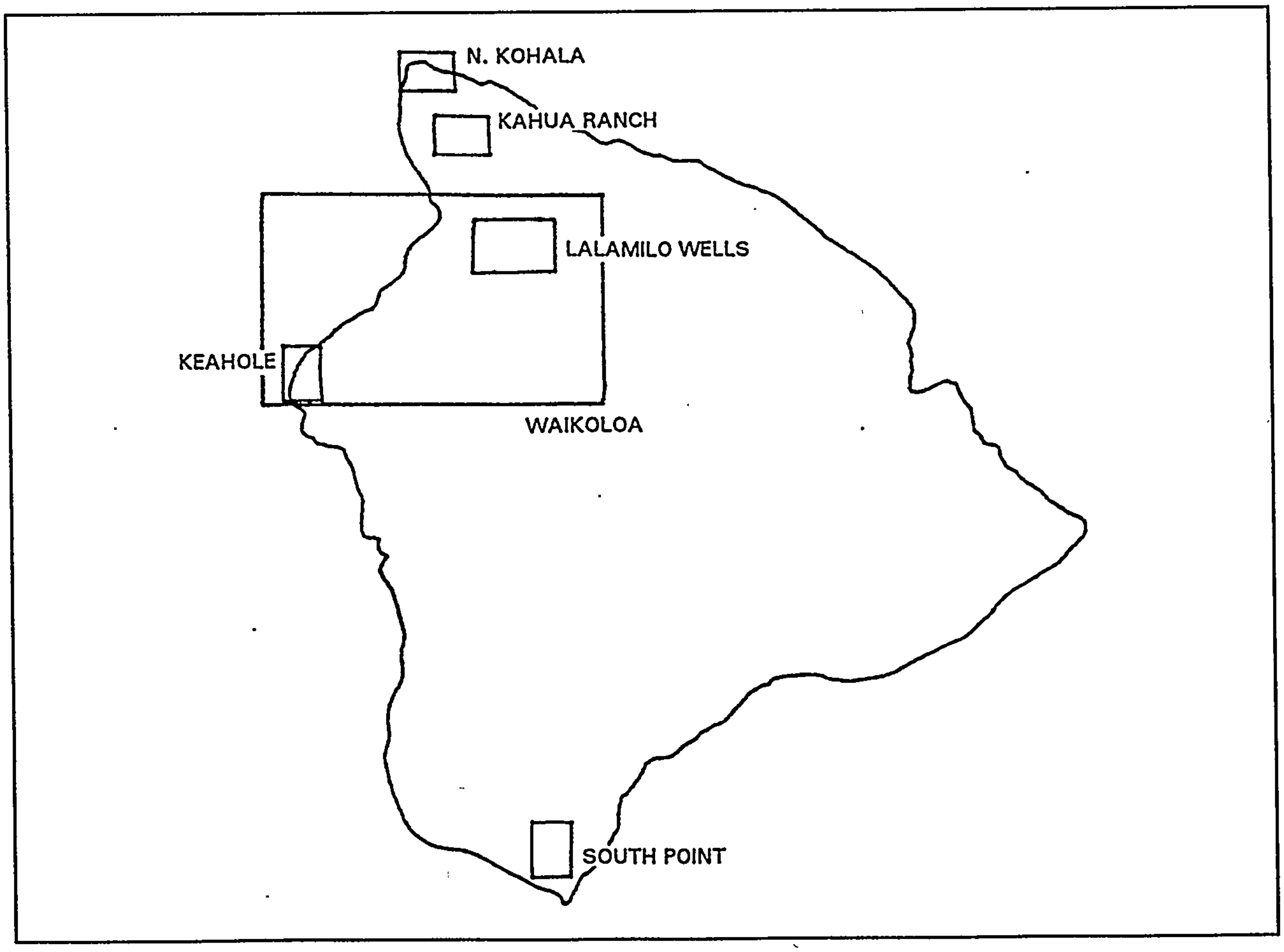


Figure 1. Hawaii Project Sites

WIND

On Hawaii, Mauna Loa and Mauna Kea, the two tall volcanoes on the island, represent significant barriers to the trade winds. As a result, the wind on this island is diverted to the north of Mauna Kea and accelerated through the Waimea saddle and over the Kohala Mountains, producing a several areas of significant wind resource. To the south of Mauna Loa, the diversion of the wind produces a smaller area of significant wind resource at the southern point of the island. Potential projects were identified as shown in Table 1.

Table 1. Hawaii Wind Projects

Island	Technology	Ranking Code	Description
Hawaii	Wind	W1	Lalamilo Wells
Hawaii	Wind	W2	North Kohala
Hawaii	Wind	W3	Kahua Ranch
Hawaii	Wind	W4	South Point
Hawaii	Wind	N/A	Small-Scale Applications

W1: Lalamilo Wells. Located in the plains between Kohala and Mauna Kea, the Lalamilo Wells area is the site of an existing 2.3 MW wind farm made up of 39 Jacobs 17 kW and 81 Jacobs 20 kW wind turbines. There are no publicly available resource data at this site; however, a number of wind energy developers have monitored the area and have proposed projects, which testifies to its value as a potential project site. The land is zoned for agriculture and currently used primarily for grazing. It is owned by the state and a portion of the land has been leased to the County of Hawaii Department of Water Supply for wells. (The County currently purchases the energy from the wind farm.) The terrain is gently sloping and poses no problems for development or operation. The existing transmission line limits additional development to less than 3 MW; however, an upgrade to the line, or a new line could be installed for a project without severely penalizing the economics of a potential project. Another benefit to this project location is that it is centrally located in the area of the island projected for the fastest load growth in the future and generation projects on this side of the island are desirable for the utility. In addition, because the water department is satisfied with their existing contract to purchase the wind energy, the possibility of selling energy to a third party exists in this area. No major conflict is expected with biological resources and the existing wind farm is not visible from any tourist areas. Some of this area has been targeted by the Division of Historic Preservation for preservation because it is part of the early Hawaiian Waimea field system and remnants of agricultural terracing and habitation are abundant. At a minimum, replacement of the existing wind farm should be permitted. In addition, neighboring landowners such as Parker Ranch, are open to consideration of a wind energy project. A map of one potential location for a project in this vicinity is provided in Appendix E.

W2: North Kohala. The North Kohala area has long been considered to have good wind resources despite a lack of high-quality data. This area is owned by Chalon International and their current land use plan has set aside land parcels for renewable energy development. This land is currently zoned for agriculture. Other planned development in the area includes tourist resorts, housing, and golf courses. The Department of Water Supply has also identified this area as the most likely location for the near-term installation of additional water wells to support the anticipated growth in the Kona and Waikoloa areas. Although there is limited utility access at this time, the development of these other projects will require an additional transmission line. The proposed site is located in the lowland area of North Kohala, away from significant biological resources. A Marine Conservation District, Lapakahu State Park, is located on the coast but should not be affected by the proposed project. There are cultural sites in the vicinity, including King Kamehameha's birthplace, but no conflict is foreseen. Because of the resource and transmission uncertainty, this project is ranked below Lalamilo Wells. Appendix E provides a map that shows the land parcels which have been set aside for renewable energy development.

W3: Kahua Ranch. Located on the Kohala ridge line, Kahua Ranch is also the site of a small existing wind farm. A larger wind farm was recently removed due to the poor reliability of the equipment.

The area has been shown to exhibit exceptional wind resources. The terrain consists of rolling hills and the location of the previous wind turbines is situated between two cinder cones. Kahua Ranch is a diversified ranch that includes carnation growing, grazing, and wind energy. The potential project site is currently used for grazing. The land is zoned for agriculture; however, the state has proposed re-zoning to conservation because of biological resources. The landowner is a long-time advocate of wind energy and has argued against the re-zoning on the basis that the land has long been used for grazing. The existing transmission is limited to approximately 5 MW; however, an upgrade to this line has been discussed by the utility primarily to service proposed tourist development and water pumping wells at the end of the peninsula. It is unclear at this time who will pay for this transmission line upgrade. Public acceptance is not considered to be a problem in this area. Although this site has excellent resources and strong interest by the landowner, it is ranked below the North Kohala site because of the potential for re-zoning. A map of the site is provided in Appendix E.

W4: South Point. The South Point area is the location of the existing Kamaoa wind farm on land owned by the Bishop Estate and zoned for agriculture. Non-public data have also been collected on nearby property belonging to the Campbell Estate. The wind resource in this area is significant and the terrain is relatively flat. The power generation potential at South Point is substantial; however, the main transmission line into which the Kamaoa wind farm is connected is planned for use in delivering power from the geothermal power plant in the east (Puna area) to the loads in west Hawaii, which leaves no surplus transmission capacity. There are no transmission upgrades planned for this line, so further projects at South Point are unlikely unless the power can be used on location. There is little anticipated load growth in this area. An additional complication for this area is the significant amount of cultural and biological resources. Hawaiian Homes owns the land to the south of the existing wind farm and they have indicated that they would not consider any additional development under any circumstances. As a result of these factors, additional wind energy development at South Point is not likely to occur before the previously discussed projects on Hawaii. A map of the South Point area showing the location of the existing project is provided in Appendix E.

SOLAR

Solar resources for Hawaii are concentrated on the western side of the island. The potential project sites for large-scale solar applications are presented in Table 2 and discussed below. Other areas that were considered and eliminated included South Point (limited transmission and environmental conflicts), Kau Desert (competing land use), and the Humuula saddle (endangered species, volcanic hazards).

Table 2. Hawaii Solar Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
HAWAII	SOLAR	S1	WAIKOLOA
HAWAII	SOLAR	S2	KEAHOLE POINT
HAWAII	SOLAR	S3	NORTH KOHALA
HAWAII	SOLAR	N/A	SMALL-SCALE APPLICATIONS

S1: Waikoloa. This broad regions includes the Waikoloa general vicinity from Lanuipuaa to Kawaihae along the coast and inland toward Waimea. The better sites are towards the coast; however, significant tourist development on the coast may make inland sites more feasible. There is an excellent solar resource in the entire area that has been documented by a number of data sources, including both global and direct radiation data. Land zoning is a mixture of agriculture, urban, and conservation. The terrain is relatively flat near the coast with slopes as great as 5% further inland. A map showing the Waikoloa area is provided in Appendix E. An exact project site has not been identified because there are numerous large parcels of undeveloped land that would be suitable for development in this area. There are numerous landowners in this vicinity including the Parker Ranch, Transcontinental

Development Corporation, and the State. New generation on this side of the island is desirable due to the significant load growth. HELCO is planning generation additions in this area and there are several 69 kV transmission lines and substations within the general area. From a transmission standpoint, this area is currently the most desirable location on the island to add capacity. The Waikoloa area is well known for abundance of rare anchialine pools; however, it should be possible biological conflicts to avoid through siting. There are a number of cultural sites on the makai side of the highway. These can also be avoided through appropriate siting.

S2: Keahole Point. This area is north of Kona and south of the Waikoloa area. The Natural Energy Laboratory of Hawaii (NELH) is located in the Keahole Point Area. There is a long period of record of measured global horizontal and diffuse horizontal solar radiation data maintained by the NELH that indicates that the direct insolation is 13% higher than at Manoa. There is land zoned urban in the vicinity of NELH and surrounding land is zoned conservation. The majority of the land is owned by the State. In the immediate vicinity, possible competing uses for the land include the expansion of the Kona airport, additional development at NELH, or the leasing of the land near NELH for aquaculture tenants. Should these potential developments occur, however, there is additional land in the broader area that is likely to be available. The terrain is fairly level and suited to all types of solar development. However, land grading and development costs can be high in this area and this may affect project siting and costs. An additional benefit for solar trough technology is that NELH has the ability to provide sea water for cooling. There are existing transmission lines in the vicinity and, as previously, discussed, generation on this side of the island is desirable. No biological or cultural conflicts are foreseen. A map of the area with one potential project site identified is provided in Appendix E.

S3: North Kohala. North Kohala area is thought to have the highest insolation of the three solar sites considered on Hawaii. Its steep slope makes it undevelopable for parabolic trough systems, but parabolic dish concentrating systems or photovoltaics are possible. As discussed for wind energy projects, Chalon International, one of the landowners in this area, has set aside parcels of land for renewable energy development. Other landowners include Kohala Ranch, the Queen's medical center, Parker Ranch, the State, and Hawaiian Homes. At present, the 69 kV transmission line ends at the Kohala Ranch substation, about 8 miles south of Mahukona. However, additional load growth at the northern end of the peninsula is planned and a transmission line brought in to serve this load could be used for any renewable energy project. Although biological and cultural resources exist, conflict should be avoidable through appropriate siting. A map of the parcels set aside for renewable development is provided in Appendix E.

BIOMASS

Potential biomass projects are classified into two categories based on the source of the biomass: energy crops and organic waste. Future work will further categorize projects based on the conversion technology that is utilized and the end energy product, either transportation fuels or electricity. For Phase 1, potential projects mean (1) that there is an area of land available and suitable for the production of a biomass energy crop or (2) that there are available and potentially collectable organic waste products not currently being converted into an energy end-product. Because the processing facilities were generally assumed to be located at existing mill sites, it was also assumed that transmission lines to the sites were adequate. However, in many cases new processing facilities or modifications may be required for biomass crops other than sugarcane. Similarly, because of the existing agricultural use of the land, environmental and cultural conflicts or public opposition are not likely to develop based on changing the type of crop at the site or using existing processing facilities. Table 3 summarizes the characteristics of the potential biomass projects identified for Hawaii. These projects are discussed in more detail below. Maps showing the location of the proposed energy crop projects for various species are included in Appendix J.

B1: Paaukau. One of the most likely energy crop projects in the state is the use of these lands that were previously used for sugar by Hamakua Sugar Co. Because of Hamakua's recent bankruptcy, the

Table 3. Hawaii Biomass Projects

TREE CROPS

Location	Company	Acres Considered	Productivity Range (dry/ton/ac/yr)	Acres	Annual Production (dry ton/yr)
Paaukau	Hamakua Sugar Co.	41,794	13-18	5,671	87,010
			11-13	1,132	13,510
			8-11	4,631	43,040
Pepeekeo	Mauna Kea Agribusiness Co.	32,246	13-18	37	560
			11-13	5,995	68,240
			8-11	13,042	124,990
Pahala	Ka'u Agribusiness Co.	20,007	13-18	1,831	32,670
			11-13	0	0
			8-11	358	3,240

GRASS CROPS

Location	Company	Caneland Acres	Acres Harvested	Production (dry ton)	Annual Production (dry ton/ac/yr)
Paaukau	Hamakua Sugar Co.	27,837	7,586	190,790	12.6
Pepeeko	Mauna Kea Agribusiness Co.	14,683	5,793	120,740	10.4
Pahala	Ka'u Agribusiness Co.	12,559	4,374	123,180	14.1

Note: Grass production estimates based on actual sugarcane harvests, biomass to energy crop choice would likely be custom suited to the application. Short rotation grass crops other than sugarcane may be viable alternatives.

ORGANIC WASTES

Region	Geographic Area	Organic Waste (dry ton/year)	Primary Components
Region G & H	Northwest side of the island	71,550	95% of total is dairy, green, & foodwaste
Region I	Northeast corner of the island	124,480	unknown

land will be available for other crop considerations, and, as such, it is the highest ranking biomass project on Hawaii. The climate and soil conditions are particularly good for tree crops; however, grass crops were also considered at this site. Due to the bankruptcy, ownership and future plans are unclear at this time.

B2: Pepeeko. This area, also considered for both tree and grass crops, also has particularly favorable climatic and soil conditions for a tree crop. The landowner, C. Brewer and Co., Ltd., is interested in developing 7,000 acres for a tree project to make particle board.

B3: Pahala. The third energy crop project considered, Pahala, is owned by Ka'u Agribusiness Co. (C. Brewer and Co., Ltd.). This is the least productive tree crop land, but the most productive sugar crop land on Hawaii. Although this area has significant potential, it is ranked third because it is currently a productive facility and not presently under consideration for an energy crop.

Organic Waste. There are two plausible areas with enough resource of organic waste to support organic waste processing facilities on the big island, one in the west and one in the east. Regions G and H comprise the western coastal areas from South Kona to Kohala. Regions I and J comprise the northeastern area of the island from greater Hilo to the Hamakua Forest.

HYDRO

There are a significant number of small hydro facilities operating on Hawaii and a new 10 MW project was recently put on-line. The hydro resource on this island is concentrated in the Kohala area and the Hamakua coast. Upgrading some of the existing or abandoned facilities and ditch systems has been evaluated by HELCO and others; however, at this time, additional upgrades were determined not to be feasible above those either recently completed or in process. A hydro project on Hawaii on the Honolii Stream was denied a permit in the late 1980s due to concerns over potential effects on surfing conditions and aquatic life. Although resource potential exists on this stream, it is not considered to have development potential because of the denied permit. Several new potential hydro projects were recently proposed by the same company that developed the new 10 MW project in the Hamakua coast area. Although they are expected to face public opposition, they are presented below as potential projects and summarized in Table 4.

Table 4. Hawaii Hydro Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
HAWAII	HYDRO	H1	UMAUMA
HAWAII	HYDRO	H2	KAWAINUI
HAWAII	HYDRO	H3	KOHOLAELE, LUAHALA, KAULA

H1: Umauma. The Umauma Stream is located on the Hamakua coast and drains just north of Hakalau. It is anticipated that a project of approximately 15 MW could be installed at this location. This project has not been previously proposed and because of its size and because public acceptance is anticipated to be more likely at this location than other proposed projects, it is the most likely of the hydro projects on Hawaii to be developed.

H2: Kawainui. The Kawainui Stream is also located on the Hamakua coast south of the Umauma project. It is anticipated that a project of approximately 6 MW could be installed at this location. This project has not been previously proposed.

H3: Koholaele, Lauhala, Kaula. These three potential projects are located on the Hamakua coast and they drain between the towns of Paauilo and Ookala. They are less likely to be developed than the two previously discussed on Hawaii because, in order to be developed, it will be necessary to reach an agreement with parties that use the water for irrigation.

WAVE, OTEC, AND GEOTHERMAL

No specific wave energy projects were identified on the island of Hawaiiin this phase of the project. Additional investigation of this technology will be considered in future phases of this work. A single project site was chosen for further analysis of OTEC systems at Keahole Point (Table 5). The project site was chosen based on the existing location of the HayaiiNatural Energy Laboratory, which is the site of a currently operating experimental OTEC facility. The area is zoned urban and the site was chosen because of its proximity to deep ocean waters that are a requirement for OTEC technology. The geographical features and existing installed equipment make it a natural choice for further expanded efforts to bring OTEC to the reality of utility-scale power generation. A single project site was also chosen for geothermal power development, the Kilauea east rift zone. It is assumed that the potential sites will be chosen in areas of gentle to moderate terrain.

For OTEC, additional resource areas for the deployment of the technology have been identified off the Puna coast on the eastern side of Hawaii and near South Point. Transmission constraints and environmental and cultural conflicts are likely to prevent development near South Point. The northeast

Table 5. Hawaii Wave and OTEC Projects

Island	Technology	Ranking Code	Description
Hawaii	OTEC	O1	Keahole Point
Hawaii	Geothermal	G1	Kilauea East Rift Zone

coastline of the island has also been identified as having significant wave energy resources. Due to the protected nature and limited transmission access on the northern portion of this coastline, potential development is likely to be more suitable for the Hilo area, despite the lower resource.

Maui

The land availability screening process eliminated the vast majority of Maui's land from consideration; however, on the limited amount of suitable land, a number of potential renewable energy projects that appear to have significant development potential were identified. The mountain regions of Maui are zoned conservation and are largely national park and forest reserve lands. These and most other conservation lands are inaccessible for energy project development. The south side of Haleakala to the coast and the northeast side of the West Maui Mountains were eliminated due to terrain constraints and lack of utility access. The majority of Maui's remaining coastline is developed for tourism. Potential renewable energy projects are discussed for each technology in the following section. The general locations of potential project sites are shown in Figure 2.

Wind

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 north western slope of the West Maui Mountains and of lower Haleakala. A number of wind energy project sites with significant development potential are summarized in Table 6 and discussed below.

Table 6. Maui Wind Projects

Island	Technology	Ranking Code	Description
Maui	Wind	W1	West Maui
Maui	Wind	W2	McGregor Point
Maui	Wind	W3	Puunene
Maui	Wind	W4	NW Haleakala
Maui	Wind	N/A	Small-Scale Applications

W1: West Maui. Zond Systems, a wind energy developer, has negotiated a lease with the landowner, Maui Land and Pineapple, for a 10 MW wind energy project in this area. Although there is additional land in this area that may be suitable for wind energy, the landowner is reluctant to consider any additional leases for wind energy because of existing and planned tourist development. In fact, Zond's original project site was moved further inland because the landowner was concerned about its proximity to a planned golf course. Expansion may be possible in the future if the first 10 MW project proves to have little affect on other planned land uses. The land is zoned for agriculture and is currently used for grazing. The terrain is fairly complex; however, no problems are anticipated with construction or maintenance. Other land in the area is zoned for conservation (part of the West Maui Forest Reserve). Transmission lines from the northwestern slope of west Maui have remaining capacity to accommodate a project of up to 20 MW. Despite the landowner's concerns, the project is unlikely to be noticeable from the coastline developments and little public opposition is anticipated. Although this area of Maui is rich in biological resources and many cultural sites are known to exist

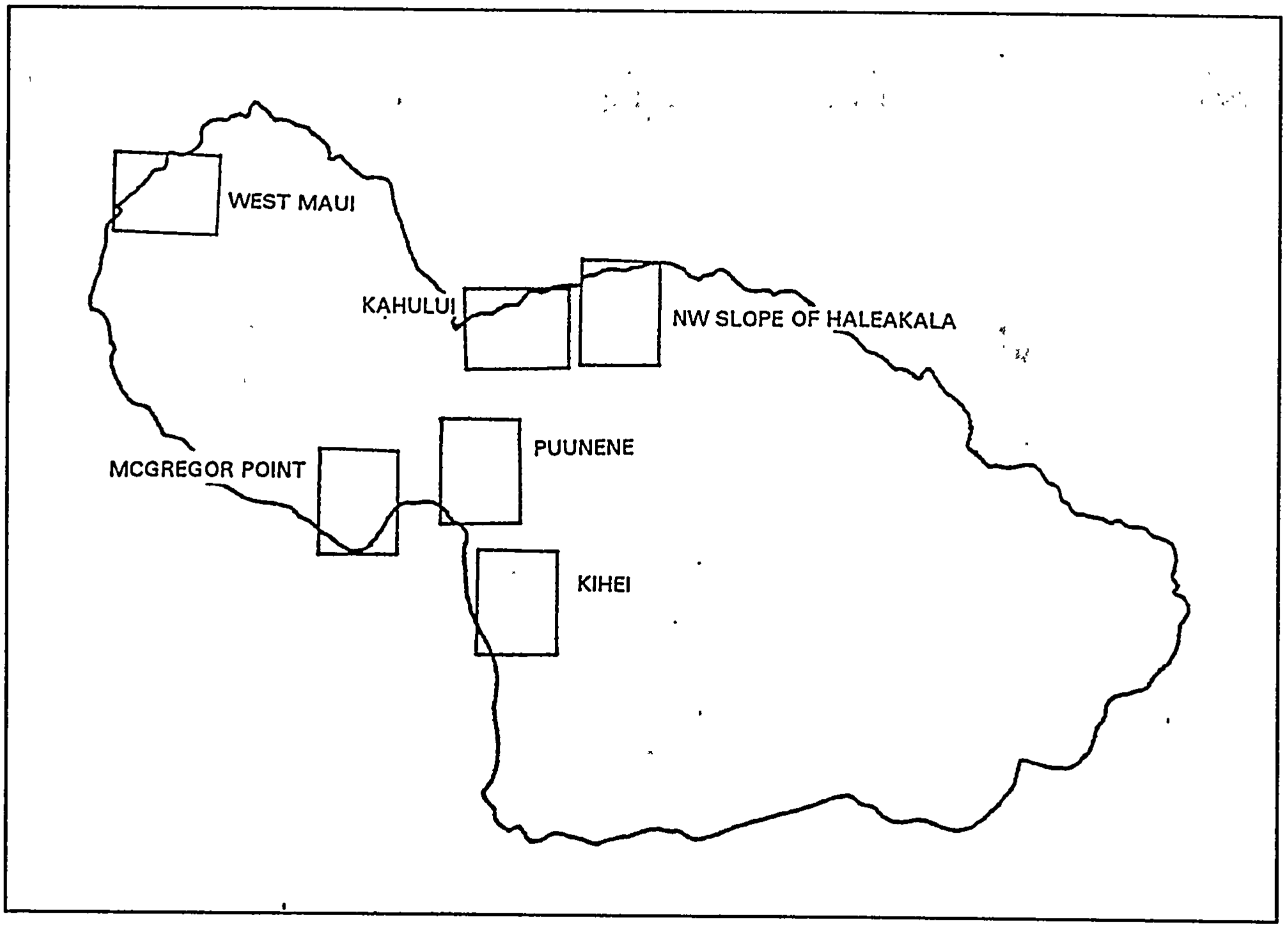


Figure 2. Maui Project Sites

here, a correctly sited development is likely to have little environmental impact. The map of the approximate project location is provided in Appendix F.

W2: McGregor Point. The highest average wind speed recorded on Maui is at the southwestern corner of the isthmus at McGregor Point. The coastal lands in that area are not available for consideration of energy projects; however, the land rising up, away from the water is zoned resource and general conservation land and could be developed for a wind energy project. The land is owned by the state and currently leased for grazing. This location is close to Maui Electric's Maalaea generating stations and there is available transmission capacity and land for a project of at least 10 MW in size. The terrain is also fairly complex; however, no problems are anticipated with construction and maintenance. In fact, Maui Electric recently constructed a transmission line over the ridge line under consideration and a potential wind project would likely be located near this line. There are no known biological or cultural resources in the vicinity that would be impacted by a wind energy project. The project would, however, be highly visible from the main road from the airport to the tourist developments in West Maui. For this reason, it is ranked lower than the West Maui project. The higher on the ridge the project is installed, the less visible it will be. A map of the approximate project location is provided in Appendix F.

W3: Puunene. The old airport site near Puunene is located in the center of the Maui isthmus approximately four miles south of Kahului on land that is zoned for agriculture. The actual level of wind resource available at this site is uncertain, although its location suggests that there is significant potential. This land is also owned by the state and the majority of the land is currently planted in sugar cane. The state, along with Maui County, is currently developing a master plan for the 1000 acre site. Due to its central location, the state is considering several potential uses for the land, including a waste water treatment plant, light industry, and tourist activities. In addition, the state would like to maintain some agricultural land in this area to serve as a buffer between Kahului and the tourist developments in Kihei. Despite these other considerations, it appears that sufficient land may still be available for a wind energy project. The land is flat and there are sufficient existing transmission lines in the vicinity to support a 10 MW project. In addition to the 23 kV transmission line and substation adjacent to the site, it is likely that transmission improvements will be incorporated into the master plan for the site. There is no foreseeable conflict regarding environmental or cultural sensitivity. Due to its location, the project will be fairly visible. For this reason and because of possible conflicts with other plans for the land and uncertainty regarding the resource, it is ranked lower than the first two projects. A map showing the state-owned land is provided in Appendix F.

W4: NW Slope of Haleakala. The northwestern side of Haleakala represents vast expanses of windy land zoned for agriculture and planted in sugar. The terrain is gently sloped and would offer no particular challenges for construction or operation of a wind energy project. The major landowner in this area, HC&S, is a large power consumer and would consider a wind energy project if it proved to be more economical than the existing land use. Note, however, that HC&S is one of the most profitable sugar producers in Hawaii and not likely to remove productive lands from sugar in the near future. For this reason, this project received the lowest ranking of the Maui wind energy projects. Nonetheless, the potential exists for a suitably sited project, perhaps on less productive land, and there is flexibility in locating an exact project site. Existing transmission lines to this area are sufficient for a project of approximately 10 MW. There are no foreseeable environmental or cultural concerns in this area. The project will not be visible to the majority of the island residents or tourists. A map showing the general area and one of many potential project locations is provided in Appendix F.

SOLAR

Maui's solar resources are concentrated on the leeward side of the island and in the central isthmus. Land with solar resources often conflicts with tourist developments. The potential project sites, shown in Table 7, were identified for large-scale solar energy applications and are discussed below. Additional areas that were considered and were eliminated included the Lahaina area due to competing uses and the tourist nature of the area.

Table 7. Maui Solar Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
MAUI	SOLAR	S1	PUUNENE
MAUI	SOLAR	S2	KIHEI
MAUI	SOLAR	S3	KAHULUI AIRPORT
MAUI	SOLAR	N/A	SMALL-SCALE APPLICATIONS

S1: Puunene. This site is the same as identified above for wind energy. There is existing global radiation data that indicate a significant resource, although there are no direct data available. A solar trough project may be feasible for this site and it may integrate well with the proposed waste-water treatment facility by providing the option of waste water effluent re-use for power plant cooling purposes. The site is also suitable for other solar technologies, including photovoltaic and solar dishes. As discussed above, the terrain and soil conditions are suitable for development, there are no cultural or environmental constraints, and there is existing transmission line in the vicinity. A solar project would be less visible than a wind project at this site; however, a solar project would occupy more land. In conjunction with the development of a waste-water treatment plant, little public opposition is anticipated. A map of the site is provided in Appendix F.

S2: Kihei. This area includes the lower southwestern slopes of Haleakala, above the tourist developments of Kihei, including the Research & Technology Center which is the location of the PVUSA site. The solar resource in this area is generally considered to be better than at Puunene, but there are also no direct radiation data available. Because of the tourist development along the coast and the growth anticipated for this region, any project development would likely be above the developed coastal band of land. The largest landowner in this area is Haleakala Ranch and they are willing to consider the use of their land for a solar energy project. The majority of the land is zoned for agriculture and used for grazing. The terrain has a much greater slope than Puunene (3-6% at best increasing to 10% or more to the south and further inland) and the soil conditions are less favorable. As a result, development of a project with solar trough technology may be more difficult than photovoltaic or solar dish technology and it is considered to be a slightly less desirable location than Puunene. There are transmission lines in the vicinity and, due to the projected load growth, this is a desirable location for new generating capacity additions. Although there are known biological resources in this general area, they are scattered. As a result, environmental conflicts should be avoidable by appropriate siting. A map of the general area and one potential project site is provided in Appendix F.

S3: Kahului Airport. This site covers the area to the south and east of the Kahului airport. The land is currently planted in sugar and zoned for agriculture. The majority of the land is owned by Alexander and Baldwin Sugar Co., Inc. Reported high winds in this area may indicate a difficulty in developing solar concentrating projects, which depend on focus for high efficiency. Replacing the sugar land with a solar project is unlikely unless it proved to be significantly more economical than the current use. The land is relatively flat and suitable for all types of solar development. There are existing transmission lines in the vicinity due to the proximity of the Kahului power plant. There are no known environmental or cultural impacts. Due to competing uses in the present as well as the future, this site is ranked below the first two. A map showing the general area and one potential project site is provided in Appendix F.

BIOMASS

Table 8 summarizes the anticipated production for the biomass projects identified on Maui and they are discussed in more detail below. Maps showing the location of the proposed energy crop projects for various species are included in Appendix J.

B1: Paia. These lands are owned by HC&S and are currently planted in sugar. Approximately 12,000 hectares were considered for use, with a processing facility located at the site of the existing mill. Of the three energy crops considered on Maui, the Paia project has the highest production per hectare for tree crops. At present, the long-term plans for this land are to continue sugar cultivation. As previously discussed, any replacement of sugar would have to show a significant economic benefit in order to be considered by the landowner. A portion of this land was also considered suitable for grass crops. It receives the highest ranking for a biomass energy crop project on Maui because of its high productivity.

B2: Puunene. Approximately 23,500 acres, also owned by HC&S and planted in sugar, were considered for use in the Puunene area. The same comments for the Paia site apply to Puunene. Because both the Paia and Puunene projects are owned by HC&S, they were considered together for grass crops.

B3: Lahaina. The third energy crop project considered for Maui is located on land owned by Pioneer Mill Co., Ltd. Although this project was also considered to be suitable for both tree crops and grass crops, it receives a lower ranking because the land is situated in a location in which a number of other potential uses would compete with a potential energy crop should this land go out of sugar production.

Table 8. Maui Biomass Projects

TREE CROPS

Location	Company	Acres Considered	Productivity Range (dry/ton/ac/yr)	Acres	Annual Production (dry ton/yr)
Paia	Hawaiian Commercial & Sugar Co.	29,516	13-18	2,174	34,690
			11-13	2,693	31,200
			8-11	6,686	61,850
Puunene	Hawaiian Commercial & Sugar Co.	23,291	13-18	0	0
			11-13	1,159	13,150
			8-11	9,078	82,300
Lahaina	Pioneer Mill Co.	15,283	13-18	17	240
			11-13	1,265	14,520
			8-11	3,726	35,290

GRASS CROPS

Location	Company	Caneland Acres	Acres Harvested	Production (dry ton)	Annual Production (dry ton/ac/yr)
Paia/Puunene	Hawaiian Commercial & Sugar Co.	35,857	17,340	519,030	15.0
Lahaina	Pioneer Mill Co.	6,648	2,013	62,810	15.6

NOTE: Grass production estimates based on actual sugarcane harvests, biomass to energy crop choice would likely be custom suited to the application.

Organic Waste. 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 central Maui. Much of the waste from these regions is currently hauled to a central landfill so there are no real additional transportation costs to be associated with transportation for an organic waste conversion facility on Maui.

Hydro

There are currently several small hydro facilities operating in Maui. Evaluation of these facilities did not indicate that any substantial upgrades were feasible above those either recently completed or in process. Only one potential new hydro project (summarized in Table 9) was identified on Maui that appeared to have some development potential and it is discussed in more detail below. As previously discussed, all hydro projects are expected to face strong public opposition.

Table 9. Maui Hydro Projects

Island	Technology	Ranking Code	Description
Maui	Hydro	H1	Wailua Iki

H1: Wailua Iki. Located on the northeastern region of Maui, a hydro project was proposed for this area by Bonneville Pacific in the 1980s, and it was strongly opposed for environmental reasons. It is anticipated that a project of approximately 3 MW could be installed at this location. Although opposition to a potential project in this area is still likely, it may be more acceptable than the majority of other potential hydro locations in the state.

WAVE AND OTEC

No specific project sites for either wave or ocean thermal on Maui were identified in this phase of the project. Previous work on the siting of OTEC projects, conducted by PICHTR, indicate that there is sufficient resource (i.e., appropriate bathymetry) for two to three floating OTEC plants off the northeast coast of Maui near Hana. The scenic beauty and protected resources of this area will likely result in significant public opposition to any land-based systems. For wave energy, the resource on Maui is concentrated on the northeastern coastline. Outside of the urban area surrounding Kahului, it is anticipated that a wave energy project would face public opposition. In addition, transmission access is limited.

MOLOKAI AND LANAI

Molokai and Lanai are both small in relation to the other Hawaiian islands and are relatively low in population density as well as the size of the island utilities. Large areas with development potential for renewable energy projects were determined to exist on each island following the land availability screening process; however, there is insufficient demand to justify a large-scale project. In addition, due to the small size of the utilities, very little intermittent power generation is likely to be valuable. Renewable energy projects on these islands can be more appropriately incorporated through demand-side (i.e., solar hot water heaters) or small-scale, dispersed generation projects (i.e., water pumping). However, because both islands exhibit significant renewable energy resources, potential utility-scale projects are discussed here on a limited basis. The utility-scale projects identified for these islands are more likely to be valuable in the event that the island populations grow, or the island utilities become interconnected. Potential projects are discussed in the following sections for each technology. The general locations of potential project sites are shown in Figure 3.

WIND

Molokai is unique among the major Hawaiian islands in that it 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. Lanai lies partly in the wind shadow of western Maui. Nevertheless, there appears to be some wind resource on the northwestern third of this island. Potential wind energy project sites for these islands are summarized in Table 10 and discussed below.

Table 10. Molokai and Lanai Wind Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
MOLOKAI	WIND	W1	WEST MOLOKAI
MOLOKAI	WIND	N/A	MISCELLANEOUS SMALL-SCALE APPLICATIONS
LANAI	WIND	W1	INLAND FROM SHIPWRECK BEACH
LANAI	WIND	N/A	MISCELLANEOUS SMALL-SCALE APPLICATIONS

W1: West Molokai. Eastern Molokai is largely zoned conservation and difficult to access; however, the wind resource of west Molokai is much more accessible and well documented. Most of the non-coastal lands of west Molokai are agricultural lands with acceptable zoning for wind energy development. There are no problems anticipated with potential development in this area with respect to terrain, landowner, or public acceptance. Environmental and cultural resources exist in this area; however, there is a large amount of land with significant wind resource available and with appropriate siting, conflicts should be avoidable. There is a small wind project currently operating in West Molokai. It is therefore unlikely, under current conditions, that any further development of intermittent energy resources will take place on this island in the near future other than small-scale projects. Small-scale projects are particularly suited to Molokai because of the cost of electricity to residential and commercial customers is high enough to make such ventures economical. Appendix G contains a map that shows the approximate location.

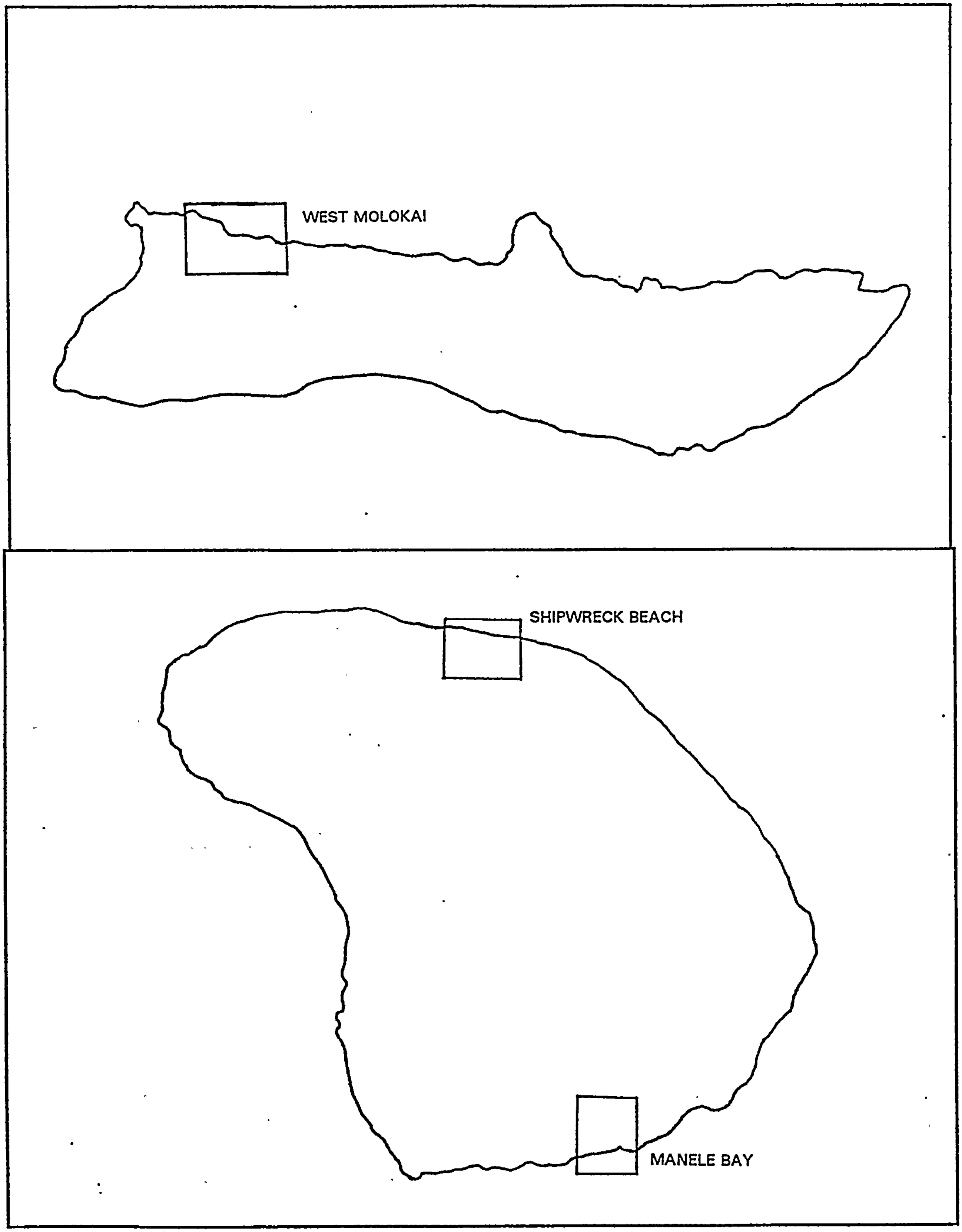


Figure 3. Molokai and Lanai Project Sites

W1: Inland from Shipwreck Beach. The available wind resource on Lanai is uncertain. Contour maps of surface trade winds indicate an annual average surface wind speed approximately equivalent to that of west Maui. Limited by the small generating capacity of the utility, there is more than adequate land available to site a wind project on the non-coastal land above Shipwreck Beach. However, there are no existing transmission lines in this vicinity and projected load growth is on the opposite side of the island. As a result, it is unreasonable to consider wind energy as a potential generating source for Lanai unless demand increases significantly above its projected levels. Like Molokai, small-scale projects are particularly suited for Lanai because of high energy prices. Because the wind resource is located away from the energy demand areas on Lanai, only limited possibilities for wind, such as water pumping for livestock, are likely. Appendix G contains a map that shows the approximate location.

SOLAR

Solar resources for Molokai are concentrated on the western half of the island. On Lanai, the solar resources are concentrated on the southwestern portion of the island. Potential project sites for solar applications are listed in Table 11 and discussed below.

Table 11. Molokai and Lanai Solar Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
MOLOKAI	SOLAR	S1	WEST MOLOKAI
MOLOKAI	SOLAR	N/A	SMALL-SCALE APPLICATIONS
LANAI	SOLAR	S1	MANELE BAY
LANAI	SOLAR	N/A	SMALL-SCALE APPLICATIONS

S1: West Molokai. With the exception of the rugged eastern portion of the island, good solar resources exist for most of Molokai. The best solar resource is on the southwest corner of the island; however, this area is not currently developed, and as such there are no load or transmission lines. Potential resort development in this area may change this situation. In the more populated areas of the island, small-scale applications are particularly well suited for Molokai because of the high cost of energy. As with wind, any utility-scale projects are not likely in the near future due to the limited utility size.

S1: Manele Bay. For Lanai, a solar project is possible in the future in the southeastern region of the island near Manele Bay because demand in this area is likely to grow due to resort development and plans for luxury homes. However, if the demand grows to a sufficient level to support a commercial solar utility project, conflicting land uses and public acceptance may become a problem. There are significant opportunities in this area for small-scale applications, however, due to the abundant solar resource and the high cost of energy.

BIOMASS

Table 12 summarizes the characteristics of a potential biomass project for the island of Molokai. The project is discussed in more detail below. Maps showing the location of the proposed energy crop projects for various species are included in Appendix J. Biomass projects were not considered for Lanai. The organic waste generated on both Molokai and Lanai is not enough to merit the construction of a waste-to-energy plant on the island.

B1: Palaau. The available land area identified as suitable for biomass crop agricultural uses has been identified as capable of producing a mixed resource of both tree and grass crops. Relative to other biomass projects on other island, this project has relatively low productivity. A processing facility would likely be located in the Palaau area near existing generation and transmission lines.

Table 12. Molokai and Lanai Biomass Projects

TREE CROPS

Location	Region	Acres Considered	Productivity Range (dry/ton/ac/yr)	Acres	Annual Production (dry ton/yr)
Palaau	Central Agricultural Area	3,786	13-18	89	1,323
			11-13	54	673
			8-11	586	4,785

GRASS CROPS

Location	Region	Total Acres	Estimated Yield (dry ton/ac/yr	Production (dry ton)
Palaau	Central Agricultural Area	5,500	18-24	99,000-132,000

Hydro

No potential hydro projects were identified on Molokai at this time. Although resource potential exists on the Halawa Stream, the landowner has indicated that he is not interested in developing the resource or providing access.

Wave and OTEC

No project sites for either wave or ocean thermal on Molokai are recommended at this time for further analysis in this study. Previous work on the siting of OTEC projects, conducted by PICHTR, indicate that there is sufficient resource (i.e., appropriate bathymetry) for a small OTEC plant that could meet all water and power requirements on Molokai. For Lanai, it would be more cost effective to supply power from Maui via an underwater cable than to consider OTEC. The proposed Molokai OTEC site would be off the northern coast close to the Kalaupapa peninsula. Because of the proposed designation of this area for a National Park, any land-based facilities would have to be located in another area.

The wave energy resource for Molokai is also centered on the northern coastline. To the northeast of the Kalahulu peninsula, no development is considered to be permissible. To the northwest, it may be possible to site the land-based support for a wave energy project; however, for either wave or OTEC projects in this area, substantial transmission upgrades will be required.

Oahu

The land availability screening process eliminated the vast majority of Oahu's land from consideration. The island of Oahu contains the largest population of any of the Hawaiian islands and, as such, there are significant competing uses for any available land. Associated with its large population, tourist industry, and industrial sector, is by far, the largest island electrical utility system. Because of its large load, penetration of intermittent generating sources should not cause any problems. Even with a conservative assumption of 10% of peak load, the near-term practical penetration limit for intermittent technologies for the island is 128 MW of capacity, of which there are now approximately 13 MW installed. However, because of competition for land and protected natural features, it is much more difficult to identify available land for renewable energy projects on Oahu than on the other islands. As a result, the interpretation of the siting criteria was broadened for Oahu to allow consideration of a number of projects with unique features such as the location of projects on military lands. In addition, the potential for projects on land that is already or planning to be developed is considered (i.e., combining solar applications on rooftops with industrial development). These types of projects may also have applications on other islands; however, their evaluation on Oahu will be representative because site-specific features are not important considerations. Potential renewable energy projects are discussed in the following section for each technology. The general locations of potential project sites are shown in Figure 4.

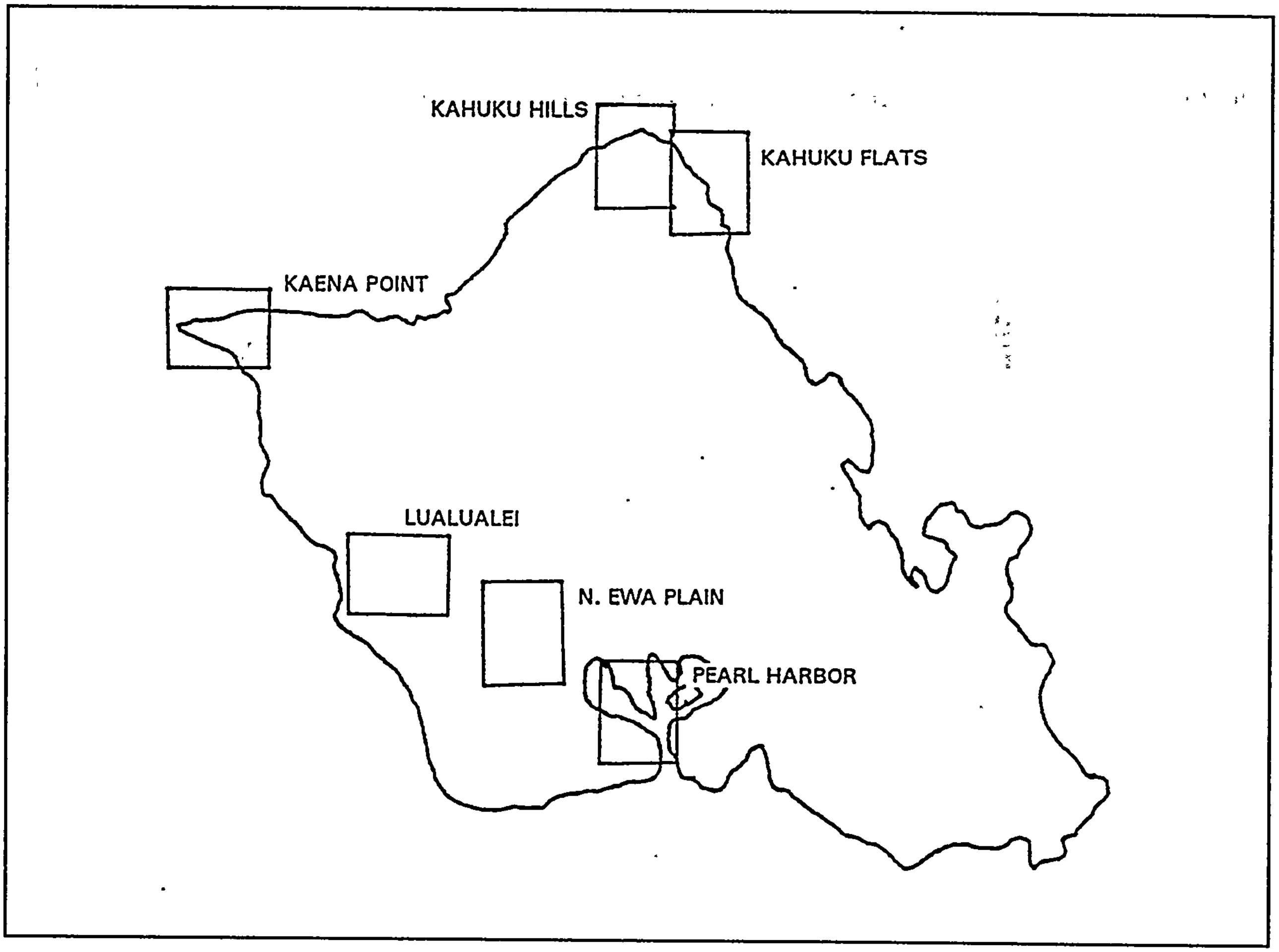


Figure 4. Oahu Project Sites

WIND

On Oahu, the Koolau mountains and the Waianae Range enhance the trade winds. The northeastern (Kahuku), southeastern (Koko Head), and northwestern (Kaena Point) tips of Oahu have areas of substantial wind resource. The combination of land available for wind development and valuable wind resource is mostly concentrated in the Kahuku area. Although two other potential project areas are discussed, they are likely to have strict limitations on land use. Potential wind energy projects on Oahu are listed in Table 13 and described below.

W1: Kahuku Hills. Kahuku Hills is the location of an existing wind farm which at one time included fifteen 600 kW Westinghouse turbines and the 3.2 MW MOD-5B, a total of 12.2 MW of installed capacity. The existing transmission line has been shown to be capable of handling about 15 MW of installed wind capacity, leaving little room for expansion; however a new transmission line is planned for the late 1990s. Based on the existing plans, the new line could handle another 10-15 MW of installed wind capacity from the Kahuku area, either in the hills or on the flats nearer the ocean. There is sufficient land in this area for a much larger project, however, and an additional upgrade or a change in the current plans is possible. Potential wind energy projects as large as 100 MW have been proposed in the vicinity. The terrain is complex; however, no problems are anticipated with construction or operation. The land is owned by Campbell Estates and the land leased to the existing wind farm is also used as an army training ground. Although the landowner is not opposed to additional development, the U.S. Army has indicated that it is against additional development. As a result, there is a potential conflict on this land. Nonetheless, it represents the only large area with

Table 13. Oahu Wind Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
OAHU	WIND	W1	KAHUKU HILLS
OAHU	WIND	W2	KAHUKU FLATS
OAHU	WIND	W3	KAENA POINT
OAHU			SMALL-SCALE APPLICATIONS

significant potential for development on the island. In the hills, there are no known biological or cultural conflicts. The existing project is visible from the coastal tourist developments in the area, but additional development is unlikely to face additional opposition. A map showing the approximate location of the existing project sites is provided in Appendix H.

W2: Kahuku Flats. The Kahuku flats are likely to be somewhat more difficult to develop than the hills. This area is also owned by the Campbell Estate and the potential project site is within the area designated for aquaculture. Some of the area in the flats is off-limits to development because of environmental restrictions, and the visual impact of turbines installed in this area will need to be given careful consideration. There are scattered wetlands in the vicinity and the James Campbell National Wildlife Refuge is an important biological resource area that provides a habitat for all four endangered Hawaiian waterbirds. The Hawaii Statewide Trail and Access System plans to develop a trail along the beach. This trail is listed as high priority because the Kahuku shoreline is one of the last undeveloped coastal wilderness areas remaining on Oahu. Although this is a relatively unpopulated area, there are tourist developments including hotels and golf courses nearby. Even with the obvious restrictions stated, expanding wind power generation in the Kahuku area is the most likely place for wind power development on Oahu. Appendix H includes a map showing the location of a potential project on the Kahuku Flats.

W3: Kaena Point. The higher ground of Kaena Point has also been identified as a high wind area. The land is owned by the state and currently zoned for agriculture. This site is limited by severe environmental restrictions near the shoreline, although some development may be possible in the higher, more exposed areas. A portion of this area is used by the military as a communications facility. There is limited transmission in the vicinity and an additional line would have to be added for any project greater than 2 MW. Public opposition is likely due to the remote, undeveloped nature of the area. As a result of these factors, this project is considered to be significantly less likely than additional development in the Kahuku area. A map showing a potential project site is provided in Appendix H.

SOLAR

Oahu's solar resource is concentrated on the leeward side of the island, primarily in areas of urban development. Potential project sites are listed below. Other areas that were considered and eliminated include Kahuku Point (wind and conflicting land uses) and Waialua (low insolation). Table 14 lists the potential solar projects for Oahu.

Table 14. Oahu Solar Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
OAHU	SOLAR	S1	PEARL HARBOR BLAST ZONE
OAHU	SOLAR	S2	LUALUALEI
OAHU	SOLAR	S3	NORTH EWA
OAHU	SOLAR	S4	EWA PLAIN
OAHU			SMALL-SCALE APPLICATIONS

S1: Pearl Harbor Blast Zone. Although the southern region of Oahu is recognized as having significant solar resources, existing urban development prohibits the consideration of a large solar facility. The Blast Zone, the area within a radial distance of 7,405 feet of the munitions magazines located on the West Loch of Pearl Harbor, is largely undeveloped due to the Navy's restriction that no occupied structures be constructed in that area. A solar energy conversion facility could be constructed in this area, with the control facility located beyond the borders; however, the Navy's position regarding the construction of a solar energy conversion facility on this land has not yet been ascertained. The entire area is nearly level and zoned for agriculture. Existing land uses in the vicinity include sugar cultivation and a golf course. The site is centrally located to HECO's load and a number of 46 kV transmission lines exist in the vicinity; however, they are heavily loaded and a transmission upgrade may be necessary for project development to occur. The area provides an important ecosystem for waterbirds, but a solar facility is unlikely to have a significant impact. Due to the developed nature of the region, public opposition is unlikely. Despite the complications of developing a project on military land, this site is ranked highest of the Oahu solar sites because of its central location and good resource. A map of the area is provided in Appendix G.

S2: Lualualei. The Lualualei area is a large flat valley situated to the west of the Honouliuli Mountains. The most extensive tracts of open land that offer the potential for economical solar generation facilities are on land that is under Navy control at the Navy Radio Transmission facility. It is unlikely that most of these areas would be available for development. The land is relatively flat and zoned for agriculture. Land closer to the water is owned by the Hawaiian Homes trust. At present, conflicting land uses may be an issue for either of the two owners. Changes in military land use may make this a desirable location in the future. There are several 46 kV transmission lines in the valleys, although new generation is expected to require some transmission line additions. Little biological, cultural, or public acceptance conflicts are anticipated. This site is ranked below Pearl Harbor because of its more remote location. A map of the area is provided in Appendix H.

S3: North Ewa Plain. This region includes agricultural sugar fields north of Ewa, particularly those north of Highway H1, along Highway 750. Although the solar resource in this area is lower than the coastal areas, land is perceived to be more readily available for a project of this type than land closer to the coast where the resource is greater. As previously discussed, the replacement of sugar lands would be considered only if the project was significantly more economical. Other competing land uses include urban expansion. The majority of the terrain is gently sloped and the land is owned by the Campbell Estate and the State of Hawaii. There are transmission lines in the vicinity; however, they are heavily loaded. There are no biological or cultural conflicts known to exist. Although this site does not have the complications of development on military land, it is ranked below the first two projects due to its lower resource and the potential for competing land uses in the future. A map showing one potential project site in this area is provided in Appendix H.

S4: Ewa Plain. This site region includes land adjacent to Barber's Point N.A.S. to the east over the entire Ewa Plain. Physically, this is the best area on Oahu for solar development because of excellent solar resources, flat land, and good transmission access. However, the area is slated for major urban expansion, including plans by the landowner, the Campbell Estate, for a major new city. Due to the many proposed conflicting land uses, this site is ranked the lowest of potential solar development areas. Of all choices of land use, a solar facility is perhaps the least valuable; however, the incorporation of a large-scale solar facility into an industrial application is possible despite the lack of available land. Because land has not been identified in this area that could be developed for a solar project, this site is ranked last. However, because the use of solar energy for industrial or commercial applications will be evaluated in later phases of the project, this project was not eliminated. The evaluation of this type of project in this area of Oahu is considered to be representative of projects of this type that could be incorporated in areas throughout the islands.

BIOMASS

Table 15 summarizes the anticipated production for the biomass projects identified on Oahu and they are discussed in more detail below. On Oahu, the many competing uses for potentially available land may limit possibilities for biomass crop projects. However, one biomass project was considered based on the potential conversion of an existing sugarcane plantation.

Table 15. Oahu Biomass Projects

GRASS CROPS

Location	Company	Caneland Acres	Acres Harvested	Production (dry ton)	Annual Production (dry ton/ac/yr)
Waialua	Waialua Sugar Co.	12,054	5,800	127,750	11.0

ORGANIC WASTES

Region	Geographic Area	Organic Waste (dry ton/yr)	Primary Components
Region C	West quarter of the island	317,500	83% of total is dairy, foodwaste, and feedlot

B1: Waialua Sugar. This is the site of the Waialua Sugar Planataion. Both the State of Hawaii and the City and County of Honolulu have expessed an interest in maintaining green spaces on the island and a 4,000 acre biomass plantation has been considered in this area. The production of the proposed project site assumes that all of the active, productive acreage of the Waialua Sugar Plantation are converted to biomass grass-crop cultivation.

Organic Waste. There is currently an organic waste processing facility operating in Waimanalo, Oahu. It draws from organic wastes generated in regions A, B, and F, which collectively comprise most of southern and southeastern Oahu. Region C also produces enough organic waste resource to support the successful operation of an organic waste processing facility. Region C represents southwestern Oahu from the Ewa plain stretching to Kaena point, west of the Waianae mountain range.

HYDRO

No potential hydro projects were identified on Oahu.

WAVE AND OTEC

In this phase, a single project site was chosen for further analysis of wave energy systems on the island of Oahu at the Makapuu Head/Waimanalo area. The project site was chosen based on the existence of resource data with sufficient characteristics for potential development. The area is zoned urban and the site was chosen because of its proximity to a load center. The wave resource has been identified on the northeast and northwest areas of Oahu. Due to the fame of the surfing conditions and the protected shoreline on the northeast coast, it is unlikely that any land-based support for a wave energy project would be permitted. Although the resource is lower, development is more likely to be feasible on western coastline, closer to the load centers and transmission access.

Due to a number of factors including current land use, near shore bathymetry (depth measurement), and location both in terms of ocean access and proximity to utility power generation plants, Kahe Point has been studied as the next potential location of research and demonstration projects for OTEC technology. In addition to this site, potential locations for OTEC facilities have been identified off the northeast coast near Kaneohe.

The wave and OTEC sites are listed in Table 16.

Table 16. Oahu Wave and OTEC Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
OAHU	WAVE	WV1	WAIMANALO
OAHU	OTEC	O1	KAHE POINT

KAUAI

The land availability screening process eliminated the vast majority of Kauai's land from consideration. The central mountain regions of Kauai are zoned conservation and are largely park and forest reserve lands. These and most other conservation lands are inaccessible for energy project development. The majority of the north side of the island was eliminated due to zoning, terrain constraints, and no utility 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 committed to other uses. As a result, locating energy projects near the energy load is difficult.

Due to the impact of Hurricane Iniki, it is also more difficult to project the future electricity demand in Kauai than for most of the other islands. Also, other than for biomass and hydroelectricity, the use of renewable energy for electric power remains largely unexplored and limited resource data are available. Although Kauai appears to have sufficient resources, it was difficult to find acceptable project sites for development of renewable energy projects. Potential renewable energy projects are discussed in the following section for each technology. The general locations of potential project sites are shown in Figure 5.

Due to overloading conditions that occurred prior to Hurricane Iniki along the transmission line passing through southern Kauai, there is a plan to upgrade the transmission capacity in this area by installing a 69 kV transmission line. So, while there is not currently any surplus transmission capacity, it is anticipated that the addition of a new transmission line will allow additional installed capacity in southern Kauai. The transmission line that runs across northern Kauai is also a 57.1 kV line with a planned upgrade to 69 kV. Based on information from before the hurricane, there is some limited available capacity for power generation additions along the northern transmission corridor.

WIND

On Kauai, the trade winds are forced to flow around the central mountain mass of the island. The prime wind resource appears to be on the southeastern and northeastern coasts of the island. However, there has been limited wind resource assessment on Kauai. Unfortunately, the coastal areas are either developed for tourism or planned for urban expansion. As a result, there is very limited land available for potential renewable energy projects to be developed on Kauai. Potential wind energy projects are listed in Table 17 and discussed below.

Table 17. Kauai Wind Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
KAUAI	WIND	W1	N. OF HANAPEPE
KAUAI	WIND	W2	S. OF KILAUEA/ANAHOLA
KAUAI	WIND	W3	PORT ALLEN
KAUAI	WIND	N/A	SMALL-SCALE APPLICATIONS

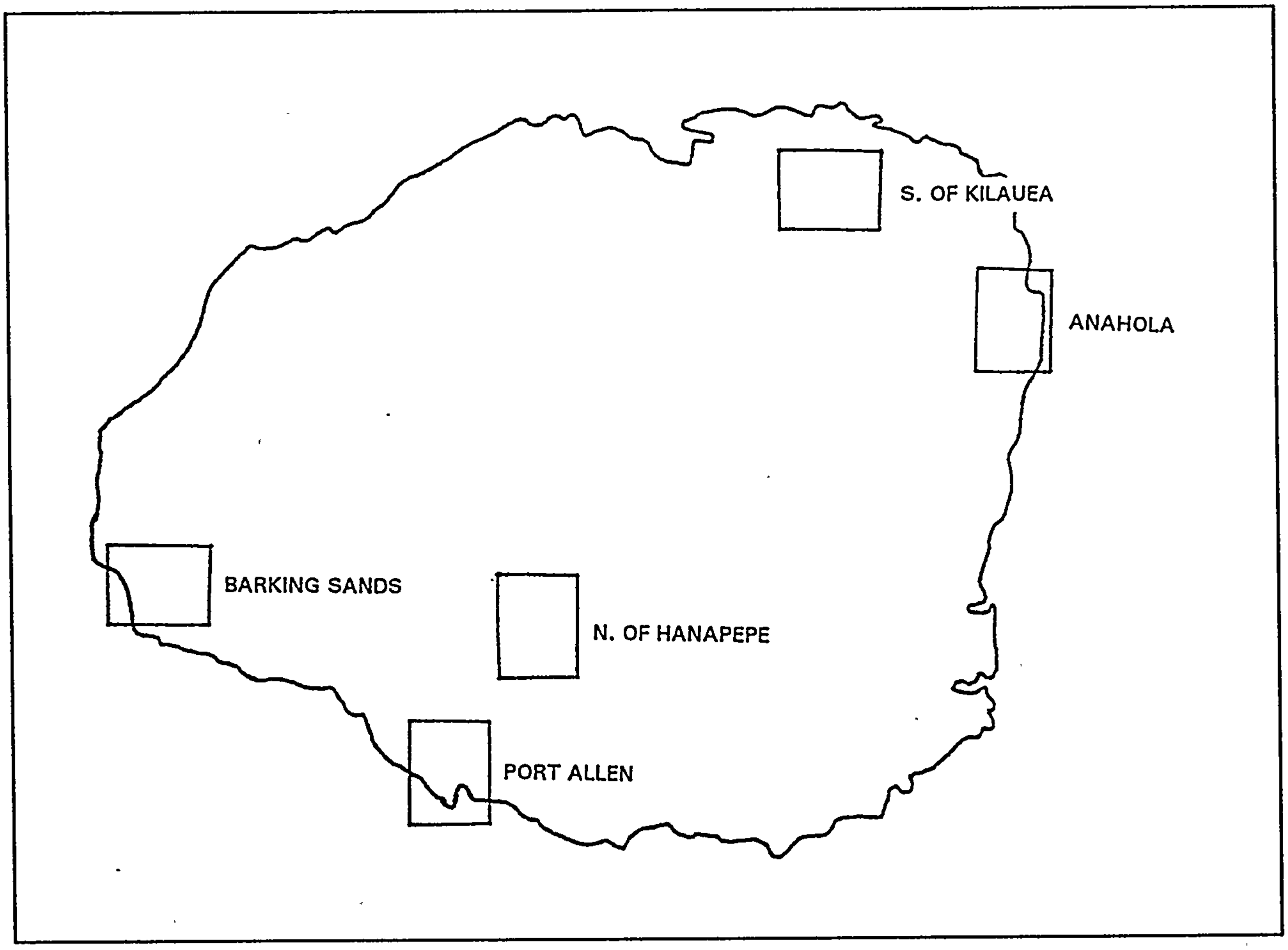


Figure 5. Kauai Project Sites

W1: N. of Hanapepe. North of Port Allen and Hanapepe, there are mountain gorges that are thought to act as funnels, concentrating the effect of wind in a local area. The land in this area is zoned as agricultural land, but due to the terrain and soil type, is of little value for agricultural purposes. The land is owned by Gay and Robinson. Although the landowner is considering possible ecotourist activities in the vicinity, planned uses are not yet determined. The terrain is fairly complex and potential project sites are between 3 and 5 miles from the nearest transmission line. There are no known environmental or cultural conflicts and the project is unlikely to be visible from any tourist or populated areas. A map showing a potential project site is provided in Appendix I.

W2: S. of Kilauea/Anahola. High winds have been measured at the Kilauea Point Coast Guard Station; however, a nearby bird sanctuary and existing homes eliminate this vicinity from consideration for a wind energy project. There are no other wind data in this general area. Although it is suspected that the wind drops off considerably further inland, there may be sufficient wind for a project in some locations to the south of Kilauea and to the east of Kilauea in the Anahola area. Although the land in this area is zoned for agriculture, most of it is developed for luxury homes. The only land that was determined to be available for consideration of a wind energy project was several inland parcels owned by C. Brewer and Co., Ltd. and the Hawaiian Homes land near Anahola. At this time, the resource is unknown on these land parcels; however, should sufficient resource exist, they appear to be developable in terms of terrain, transmission access, and environmental and cultural conflicts. Maps showing the areas are provided in Appendix I.

W3: Port Allen. The Salt Pond Beach Park and Port Allen Airport are located on a peninsula that is zoned as an urban district, but adjacent to the airport is sufficient undeveloped land to site a small wind energy project. The airport is currently used for helicopter flights. The wind resource is estimated to be at the low end of the acceptable range for wind energy conversion; however, due to the limited number of potential projects on Kauai, the evaluation of this site will be considered further. A map is provided in Appendix F.

SOLAR

Southern Kauai exhibits good solar resources; however, there is a limited amount of land available in the Lihue-Poipu-Hanapepe area due to tourist development and urban housing. Only one site was considered for large-scale solar development. It is summarized in Table 18 and discussed below.

Table 18. Kauai Solar Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
KAUAI	SOLAR	S1	BARKING SANDS
KAUAI	SOLAR	N/A	SMALL-SCALE APPLICATIONS

S1: Barking Sands. The only location on the island of Kauai where data indicate that the solar resource sufficient to consider utility-scale solar energy conversion and sufficient land is available is in west Kauai in the vicinity of the Barking Sands Pacific Missile range. Toward the mountains, but still on the plain, the land is zoned for agricultural use. Some of the agricultural land is of limited value as cropland, and so, may be suitable for solar development. In addition, although the federal property of the missile range is zoned as limited conservation, the fact that there is an existing commercial-scale solar water heating unit on the property makes it likely that some kind of solar power station could be developed there as well. The area is a flat sedimentary plain with a high water table, which would have to be considered for any type of development. The Missile range is federally owned and the remaining property in the area is owned by the State. A transmission line runs through the area; however, there is very little existing or projected load growth. As a result, the utility does not consider this to be a desirable location for a generating facility on Kauai. In addition, there are significant biological (primarily waterbird habitat) and cultural (burial grounds) areas in the vicinity that may result in public opposition. Nonetheless, there is a significant amount of land in the vicinity, and a number of potential conflicts should be avoidable through flexible siting. A map showing the general area and one potential project site is included in Appendix I.

BIOMASS

Table 19 summarizes the characteristics of the potential biomass projects identified on Kauai. The projects are discussed in more detail below. Maps showing the location of the proposed energy crop projects for various species are included in Appendix J.

B1: Lihue Plantation. Although this project site is currently planted in sugar, it has fairly low productivity and thus, more probability of considering alternate crops for cultivation. The site is also located near a deep water harbor which may be beneficial for potential transportation fuel projects. The land is owned by Amfac Inc./JMB Hawaii. This is one of two projects on Kauai that was considered for both grass and tree crops.

B2: Olokele Sugar. This site is owned by C. Brewer and Co., Ltd. and located near Kaumakani on the southwest region of Kauai. It is currently planted in sugar. It is also located fairly close to a barge port at Port Allen; however, the land is less productive than the Lihue Plantation for trees. The site was also considered for grass crops. Gay and Robinson land, which is used for sugar but does not have a processing facility, was also considered for a grass crop but was combined with Olokele

Table 19. Kauai Biomass Projects

TREE CROPS

Location	Company	Acres Considered	Productivity Range (dry/ton/ac/yr)	Acres	Annual Production (dry ton/yr)
Lihue	The Lihue Plantation Co.	24,050	13-18	0	0
			11-13	7,223	82,920
			8-11	8,777	83,120
Kaumakani	Olokele Sugar Co.	32,261	13-18	0	0
			11-13	2,367	26,650
			8-11	6,815	59,260

GRASS CROPS

Location	Company	Caneland Acres	Acres Harvested	Production (dry ton)	Annual Production (dry ton/ac/yr)
Lihue	The Lihue Plantation Co.	11,220	6,971	119,100	8.5
Kaumakani	Olokele Sugar Co.	4,716	2,305	70,400	15.3
	Gay & Robinson, Inc.	2,716	1,324	46,170	17.4
Kekaha	Kekaha Sugar Co.	8,294	3,589	98,830	13.8
Eleele	McBryde Sugar Co.	7,015	5,208	93,270	17.9

ORGANIC WASTES

Region	Geographic Area	Organic Waste (dry ton/year)	Primary Components
Region M, N & O	Eastern half of the island	80,265	90% of total is green , foodwaste, & dairy

because they currently use Olokele mill and it was assumed that this arrangement would continue if another crop was cultivated.

B3: Kekaha Sugar. This project is located in the southwest region of Kauai near Kekaha. Only grass crops were deemed to be suitable for this site. The land is owned by Amfac Inc./JMB. The grass crop sites were ranked lower than the projects that have more flexibility in species production (tree and grass crops).

B4: McBryde. This project site is also located in the southwest region of Kauai near Eleele. It is currently planted in sugar and owned by Alexander and Baldwin, Inc. Only grass crops were considered at this site and it was ranked lower than Kekaha because of its lower productivity.

Organic Waste. It is estimated that collecting and combining the organic waste generated in the eastern half of Kauai would provide enough waste to be processed to make an organic waste processing facility a viable option on the island of Kauai. An additional option for organic waste that has been explored on Kauai is the use of the boilers at sugar facilities for the burning of waste products. Although this is technically viable, the Department of Health has expressed concerns over the emissions. As an alternative, several plantations have examined the possibility of burning only green waste, which should be considered as a biomass product under their existing permits. Work in this area is in progress and the results will be included in our future work.

HYDRO

Kauai currently produces more hydroelectricity than all the other Hawaiian islands combined. Additional resource potential exists in the river valleys of the northern and eastern portion of the island; however, all proposed projects have been strongly opposed. According to Kauai County planners, all of the remaining streams in Kauai are likely to be designated as special streams, which will prohibit development, with the exception of the Wailua River. On Kauai, most of the existing hydro facilities have been evaluated or are under study for potential upgrades and additional upgrades were determined to not be feasible above those either recently completed or in process. Because all the new hydro proposed for Kauai have been denied permits, it is unlikely that any additional hydro will be allowed on Kauai. However, two potential projects are still attempting development: one on the Wailua River and one on the Hanalei River. Although it is expected to face public opposition, the most likely of these to be developed is shown in Table 20 discussed in more detail below.

Table 20. Kauai Hydro Projects

ISLAND	TECHNOLOGY	RANKING CODE	DESCRIPTION
KAUAI	HYDRO	H1	WAILUA RIVER

H1: Wailua River. Potential hydro projects have been proposed for both the upper and lower Wailua River. The upper Wailua River is dependent on the Hanalei River, however, which is likely to be designated as a special stream by the State of Hawaii. Only the lower Wailua is considered to have any development potential. Development of this project may conflict with existing recreational uses of the river. Until stream designations and development standards are determined, any hydro potential is likely to be stalled. It is expected that a facility with a capacity of approximately 6 MW could be installed.

WAVE AND OTEC

No specific project sites for either wave or ocean thermal on Kauai were identified in this phase of the project. Previous work on the siting of OTEC projects, conducted by PICHTR, indicate that there is sufficient resource (i.e., appropriate bathymetry) for two to three floating OTEC plants off the northern and southern coastlines. One proposed location, near Hanalei is likely to face substantial public opposition. Projects sites near Lihue and Port Allen are more centrally located relative to the load centers and more likely to be developable.

A wave resource has been shown to exist along the northern shore of Kauai. The scenic beauty and protected resources of this area will likely result in significant public opposition to any land-based systems. In addition, limited transmission access exists in this area. Potential for wave energy facilities may be easily sited near Kapaa on the eastern coastline.

SECTION 3. MONITORING PLAN

The purpose of this monitoring plan is to develop a high-quality database that characterizes the wind and solar energy resources in the State of Hawaii in areas that appear to have project development potential. This goal is to be accomplished by identifying potentially developable project sites as described in the previous section, utilizing existing data to the fullest extent practical to characterize these sites, and installing and operating meteorological data monitoring stations where high-quality data are not available. The monitoring stations are to be operated for a minimum of one year.

The approximate equipment costs associated with this monitoring plan total $61,804, which includes 9 wind monitoring stations, 6 solar monitoring stations, and the hardware and software to transfer the data to an IBM PC. The breakdown of costs per monitoring station, and the overall cost for new equipment are shown in Tables 21 and 22. Equipment specifications and cost quotes from the equipment manufacturers for the monitoring equipment recommended for this program are included in Appendix K.

MONITORING STATIONS

In a previous study for the DBEDT entitled *Comprehensive Review and Analysis of Hawaii's Renewable Energy Resource Assessments*, RLA identified, characterized, and compiled the available wind and solar resource data throughout the State of Hawaii. Existing data and currently active

Table 21. Equipment Costs per Monitoring Station

WIND STATION

Equipment Description	90' Tower NRG 9200-21
Logger with Speed & Direction [1]	$1,610
Second Anemometer (calibrated)	NC
Extra EPROM (256k)	$40
Shelter Box	$85
Tower (stainless steel)	$1,650
Ground Kit	$50
Subtotal per Station	$3,435
Discount	25%
Total per Station	$2,576

[1] Configured with calibrated anemometer(s) and 256k hip(s).

SOLAR STATION

Equipment Description	Ascention Technology
RSR Unit	$5,700
Tripod	$275
Misc. Materials	$115
Shipping	$190
Total per Station	$6,280

Table 22. Monitoring Equipment Cost Summary

Equipment Description	NRG 9200-21 [1]
90' Wind Stations (2 anemometers) - 9 sites [2]	$25,051
Direct Radiation Stations - 5 sites [3]	$31,400
Chip Reader and Analysis Software	$970
Total Equipment Cost	$57,421
Optional Lanai Stations - Global Radiation Station	$1,440
Subtotal with Optional Equipment [4]	$58,861
Fee at 5%	$2,943
Total Equipment Cost	$61,804

[1] Cost includes 2 extra EPROMs for project.
[2] One station does not require a tower.
[3] Quotes are per J. Augustyn for Ascension Technologies equipment.
[4] All values include the 25% discount and shipping costs.

monitoring stations were identified based on both that review and continued research to identify additional data sets that were not available when the review was complied. The location of monitoring stations with high-quality data were compared to the wind and solar project sites identified with development potential in order to determine recommend sites where additional monitoring efforts would be useful in characterizing the performance of a project in these sites.

The data sets identified as useful for this study in characterizing the resource of potential project sites are not necessarily inclusive of all data collected in the vicinity of these locations. Many short-term studies have been conducted that document site wind or solar resource characteristics; however, in cases where the data quality was questioned, these data were not considered to be sufficient for accurate energy projection estimates. In some cases, data exist that represent the renewable energy resource at a site, but they are not available to the public. In these cases, the value of further data collection was assessed based on the ability of the data to increase the understanding of the site resource and increase the likelihood that the site will be developable in the future. In recommending locations for additional monitoring sites, the main criterion considered was whether additional data would promote the development of a renewable energy project in the future.

Existing high-quality data sets were obtained from a variety of sources including the Hawaiian Sugar Planters' Association, National Climatic Data Center, Hawaiian electric utility companies, the University of Hawaii, project developers, and private landowners. A summary of the characteristics of the existing data that are planned to be incorporated into this program is contained in Appendix L. In some cases, data collection is no longer continuing. However, if several years of high-quality data were available, additional monitoring in a specific location was generally not recommended. In cases where data collection is continuing, the historical data will be obtained as will the data collected during the planned monitoring program. The intent is to make available to the public high-quality data sets from both the existing and proposed monitoring stations near developable land sites.

The following sections describe the recommended monitoring plan on an island by island basis. Figures 6 through 11 contain maps depicting the potential project sites for wind and solar resource assessment and the locations of existing and proposed monitoring sites that will be incorporated into this program. The associated tables summarize the existing and proposed data sets to be used for wind and solar resource assessment. Detailed site maps for each project site can be found in the appendices of this report.

HAWAII

The existing and proposed monitoring sites for Hawaii are shown and described in Figure 6. Four potential wind energy development sites were identified for Hawaii in the previous section. Of these, additional monitoring is recommended at two sites: North Kohala and Lalamilo. There are no suitable wind data currently available at North Kohala. At Lalamilo, data are being collected by private developers; however, they are not publicly available. The proposed monitoring station at this site is recommended for a location further upwind than the current wind farm to further quantify the resource in that area. For the other two project sites, sufficient data were determined to exist and it appears likely that these data will be available to incorporate into the program.

Three potential solar project sites have been identified. Six existing solar monitoring stations are shown in Figure 6, of which four are currently collecting both global and direct solar radiation data. As a result, additional solar monitoring is recommended only at North Kohala. RLA will ensure that the existing monitoring stations are calibrated and will obtain past data sets as well as collect data on a continuing basis.

MAUI

The existing and proposed monitoring sites for Maui are shown and described in Figure 7. Four potential wind energy development sites were identified for Maui. Of these, additional monitoring is recommended at three sites. Monitoring is not recommended at the West Maui site because the site has been extensively monitored by a private developer. Even though these data may not be publicly available, additional data in this location will not serve to further project development. To represent the northwest slope of Haleakala, monitoring is recommended at the NifTAL facility site so as to use an existing tower and reduce equipment expenses.

Figure 7 depicts three existing data sets of global solar radiation data useful for this project. At the PVUSA satellite project, RLA proposes to supplement the existing global radiation data collection efforts by obtaining direct and diffuse radiation data. Solar monitoring is also proposed for the old Maui airport site at Puunene.

MOLOKAI AND LANAI

The existing monitoring sites for Molokai are shown and described in Figure 8. No additional monitoring sites are proposed for Molokai. One existing wind station provides information as to west Molokai's wind resource, and global and direct solar data have been collected near Palaau.

The existing monitoring sites for Lanai are shown and described in Figure 9. Existing data include global solar data collected at two locations on central Lanai. No additional monitoring sites are proposed for Lanai.

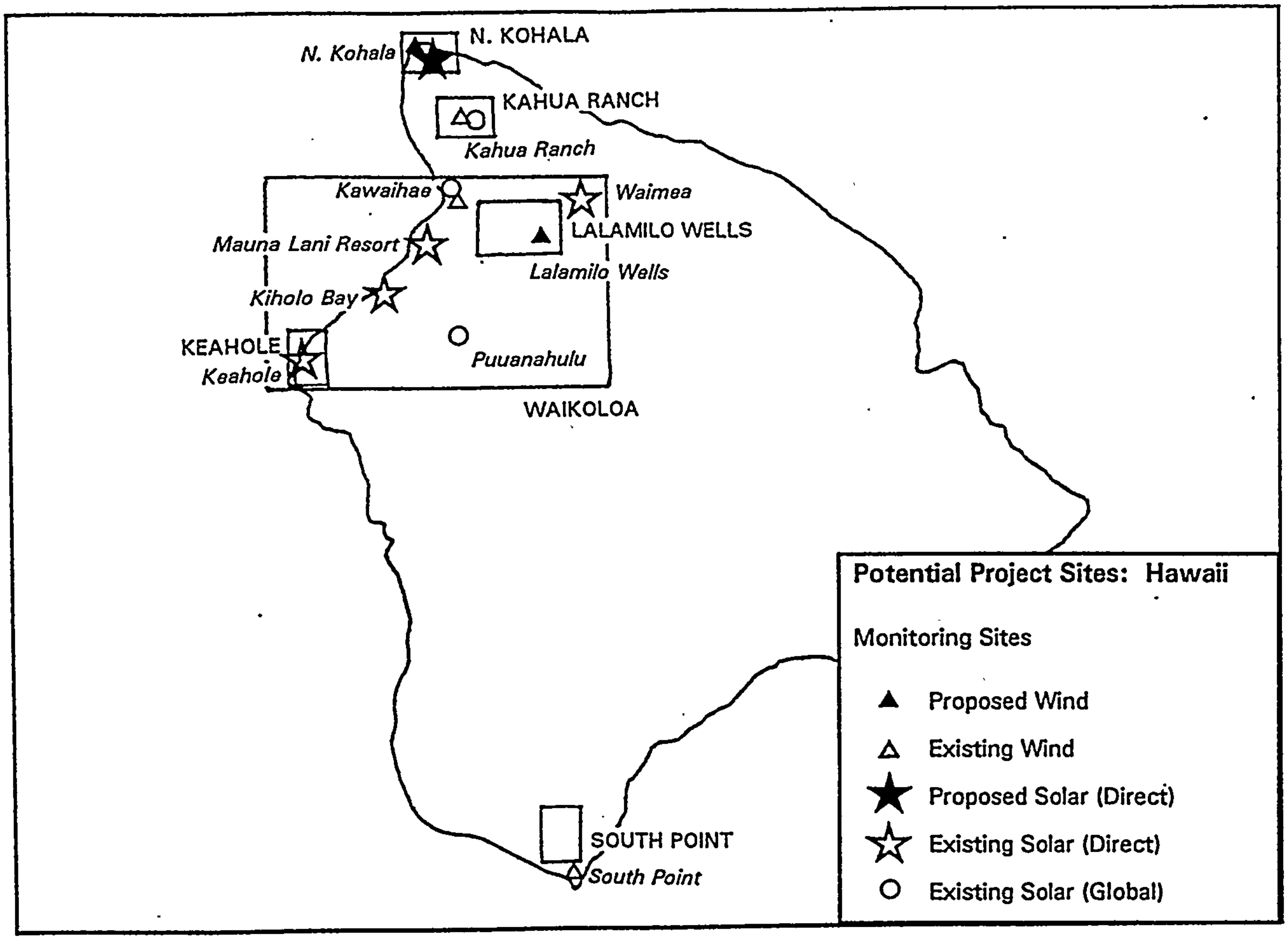
OAHU

The locations of existing and proposed monitoring locations for Oahu are shown and described in Figure 10. Three potential wind energy project sites were identified on Oahu. In the Kahuku Hills, additional data collection was not recommended because a large amount of private data already exists. The publicly available Opana data will be used to estimate production in this area. Additional monitoring was recommended at the two other potential wind energy project locations.

Solar monitoring stations are proposed to represent the Pearl Harbor Blast Zone area near the West Loch. Existing solar data will be used to represent the other identified project sites.

KAUAI

The locations of existing and proposed monitoring locations for Kauai are shown and described in Figure 11. There has been very little resource assessment data collection activity in the past. Three potential wind energy projects were identified and two are recommended for additional monitoring.



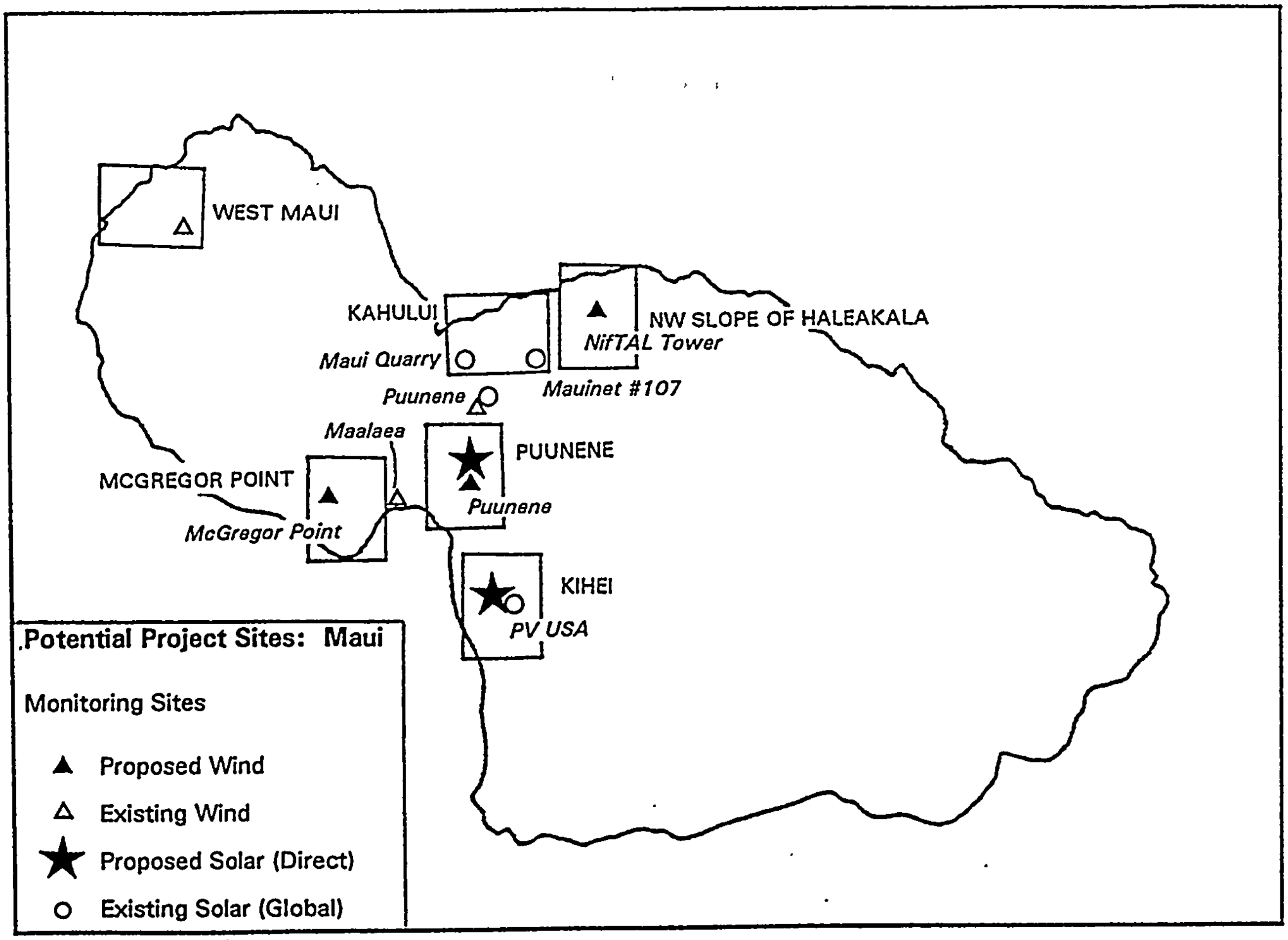
HAWAII WIND

Project Site	Data Site	Time Period	Anemometer Height	Contact Organization
Lalamilo Wells	Kawaihae	12/90 to 8/92	10,37, &64 meters	HECO
	Lalamilo Wells	proposed	90 feet	
North Kohala	North Kohala	proposed	90 feet	Chalon
Kahua Ranch	Kahua Ranch	4/92 to present	90, 140 feet	Kahua Ranch
South Point	South Point	6/87 to present		Kamaoa Wind Farm

HAWAII SOLAR

Project Site	Data Site	Time Period	Data Type	Contact Organization
Waikoloa	Kawaihae	12/90 to 8/92	global	HECO
	Puuanahulu	1/92 to present	global	HECO
	Kiholo Bay	mid 91 to present	global; direct	Bakken
	Waimea	4/93 to present	global; direct	Bakken
	Mauna Lani Resort	4/93 to present	global; direct	Bakken
Keahole Point	Keahole	3/93 to present	global; diffuse	HECO
	Keahole	1985 to 1993	global; diffuse	NELH
North Kohala	Kahua Ranch	1985 to present	global	Kahua Ranch
	North Kohala	proposed	direct; diffuse	Chalon

Figure 6. Existing and Planned Monitoring Sites for Hawaii



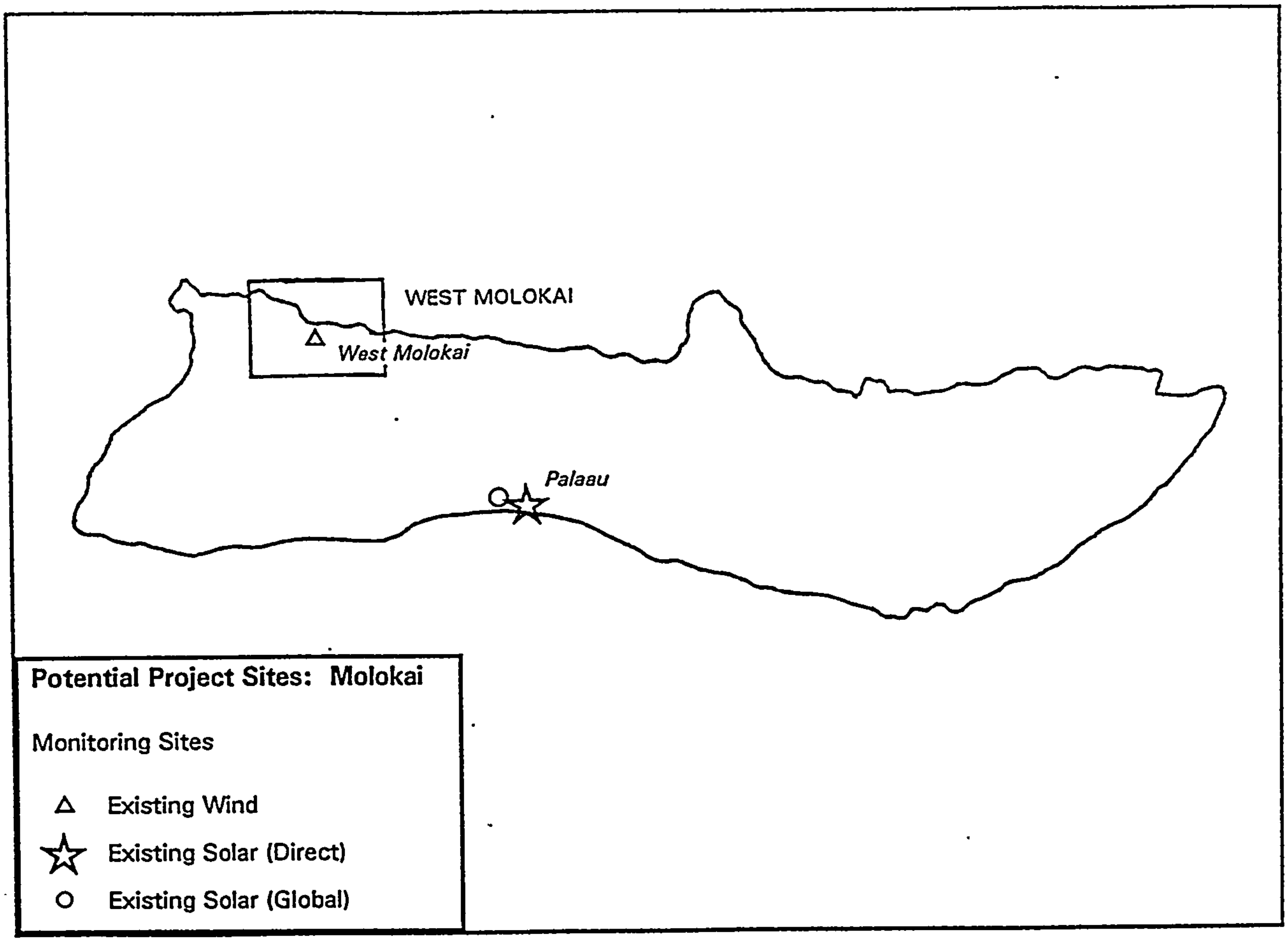
MAUI WIND

Project Site	Data Site	Time Period	Anemometer Height	Contact Organization
West Maui	West Maui	1/92 to 6/93	90, 140 feet	Zond
McGregor Point	Maalaea	2/93 to present	10, 37, 64 meters	HECO
	McGregor Point	proposed	90 feet	
Puunene	Puunene	5/92 to present	10 meter	HECO
	Old Airport	proposed	90 feet	
NW slope Haleakala	NifTAL Tower	proposed	90 feet	

MAUI SOLAR

Project Site	Data Site	Time Period	Data Type	Contact Organization
Puunene	Old Airport	proposed	direct; diffuse	
	Puunene	5/92 to present	global	HECO
Kihei	PVUSA	1989 to present	global	PVUSA
	PVUSA	proposed	direct; diffuse	
Kahului	Maui Quarry	5/92 to present	global	HECO
	Mauinet #107	1983 to 1991	global	UH (Agronomy & Soil)

Figure 7. Existing and Planned Monitoring Sites for Maui



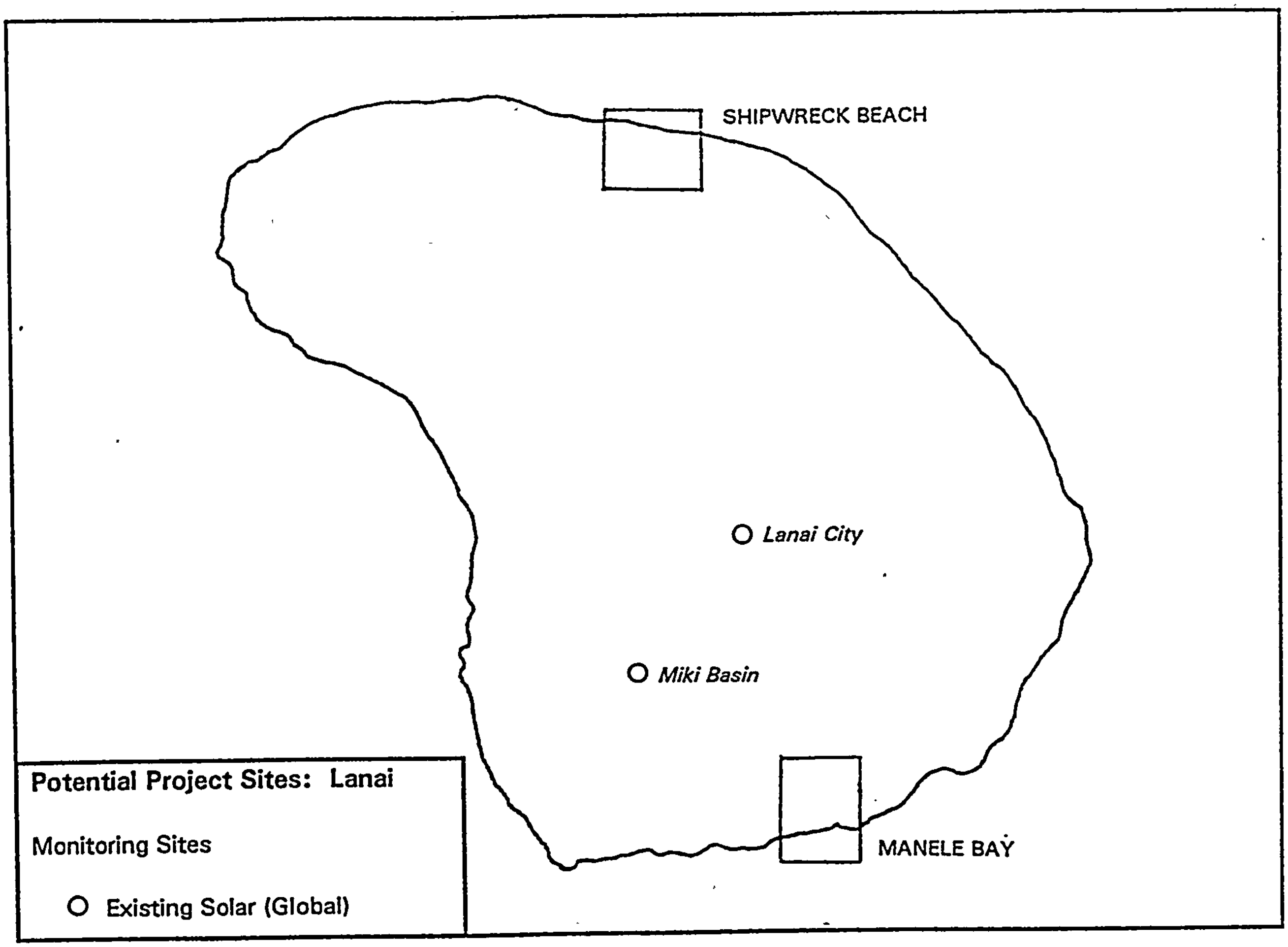
MOLOKAI WIND

Project Site	Data Site	Time Period	Anemometer Height	Contact Organization
Small Applications	West Molokai	2/92 to present	90 feet	ZOND/DBED

MOLOKAI SOLAR

Project Site	Data Site	Time Period	Data Type	Contact Organization
Small Applications	Palaau	6/92 to present	global	HECO
	Palaau	1/84 to 6/86	direct	HECO

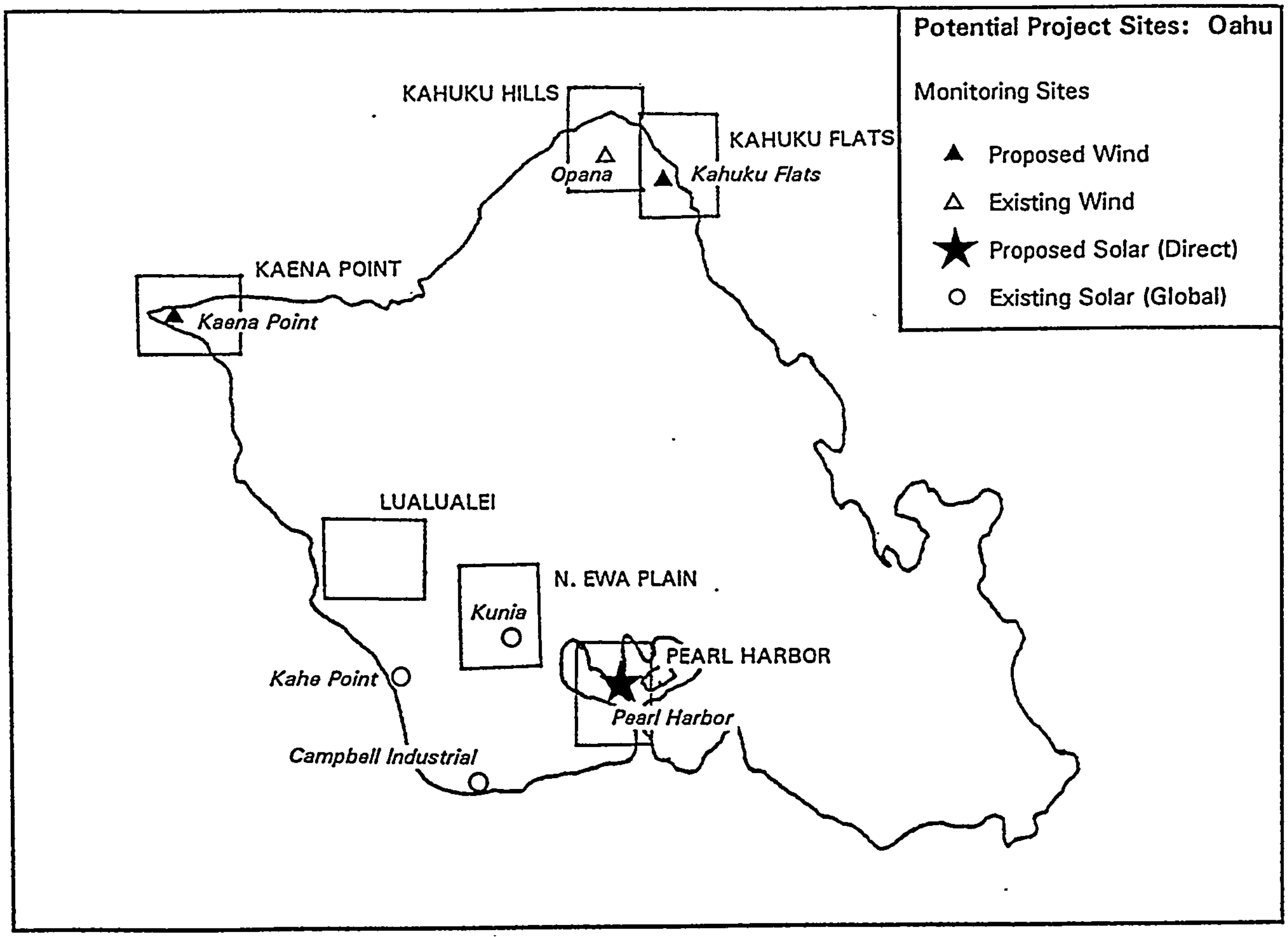
Figure 8. Existing and Planned Monitoring Sites for Molokai



LANAI SOLAR

PROJECT SITE	DATA SITE	TIME PERIOD	DATA TYPE	CONTACT ORGANIZATION
SMALL APPLICATIONS	LANAI CITY	2/92 TO PRESENT	GLOBAL	HECO
	MIKI BASIN	10/90 TO PRESENT	GLOBAL	HECO
	MANELE BAY	PROPOSED (OPTIONAL)	GLOBAL	HECO

Figure 9. Existing and Planned Monitoring Sites for Lanai



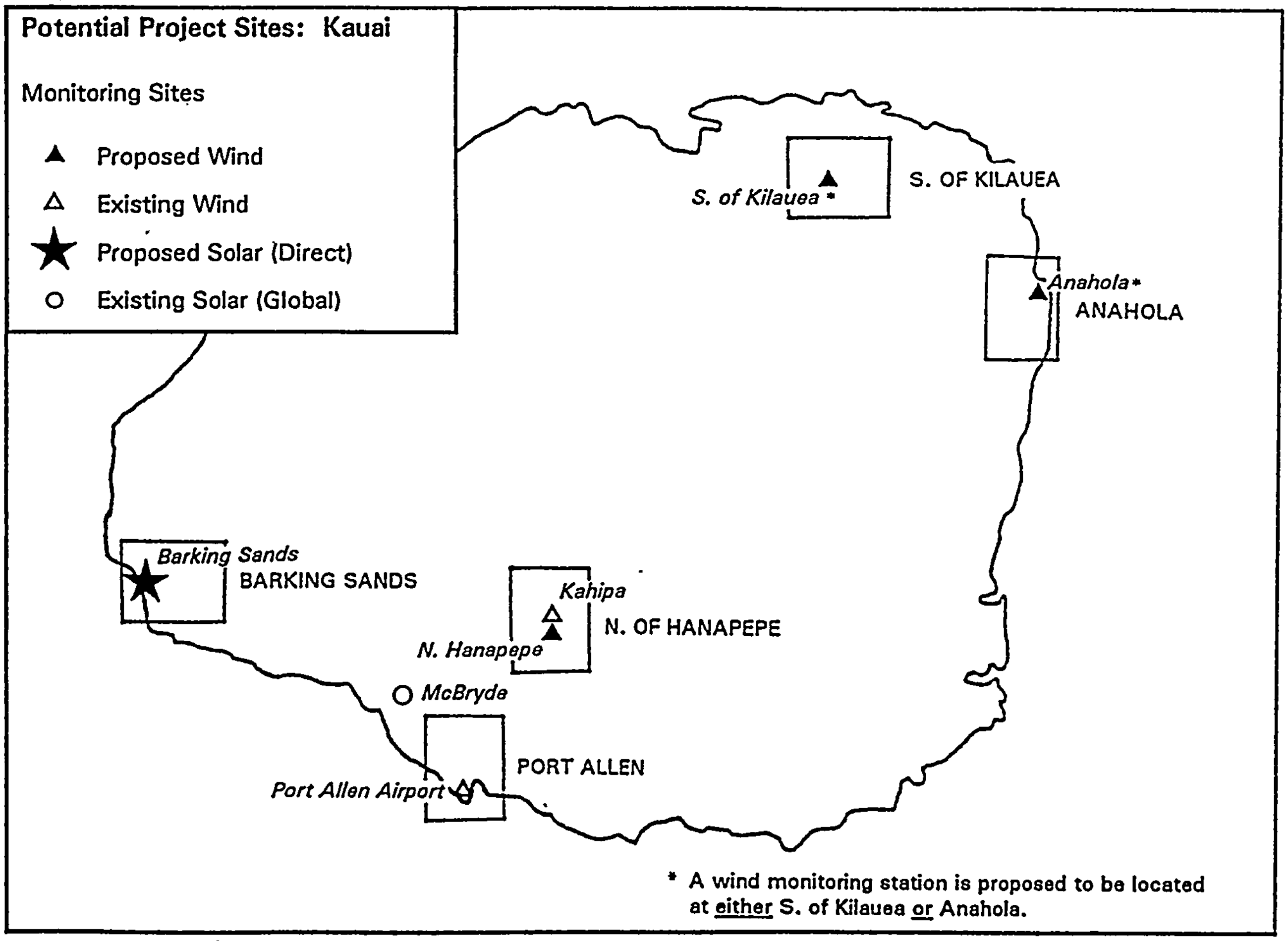
OAHU WIND

Project Site	Data Site	Time Period	Anemometer Height	Contact Organization
Kahuku Hills	Opana	3/76 to 2/83	37 feet	UHMET
Kahuku Flats	Kahuku Flats	proposed	90 feet	
Kaena Point	Kaena Point	proposed	90 feet	

OAHU SOLAR

Project Site	Data Site	Time Period	Data Type	Contact Organization
Pearl Harbor	Pearl Harbor	proposed	direct;diffuse	
N. Ewa Plain	Kunia	1989 to 1990	global	HSPA
Ewa Plain	Campbell Industrial	4/91 to present	global	HECO
Lualualei	Kahe Point	1/86 to 5/87	global	HECO

Figure 10. Existing and Planned Monitoring Sites for Oahu



KAUAI WIND

PROJECT SITE	DATA SITE	TIME PERIOD	ANEMOMETER HEIGHT	CONTACT ORGANIZATION
N. OF HANAPEPE	GAY & ROBINSON	7/85 TO 4/88	APPROX. 20 FEET	GAY & ROBINSON
	N. OF HANAPEPE	PROPOSED	90 FEET	
S. OF KILAUEA/ ANAHOLE	S. OF KILAUEA	PROPOSED	90 FEET	
PORT ALLEN	PORT ALLEN AIRPORT	2/92 TO 1/93	30 FEET	KECO

KAUAI SOLAR

PROJECT SITE	DATA SITE	TIME PERIOD	DATA TYPE	CONTACT ORGANIZATION
BARKING SANDS	BARKING SANDS	PROPOSED	DIRECT;DIFFUSE	
	MCBRYDE	1/91 TO PRESENT	GLOBAL	MCBRYDE SUGAR CO.

Figure 11. Existing and Planned Monitoring Sites for Kauai

An existing wind monitoring station that measured high average wind speeds at Kilauea Point is not shown because it is thought not to be representative of developable wind sites in the area. Additional solar monitoring is recommended at Barking Sands.

DATA COLLECTION METHODOLOGY

WIND RESOURCE MEASUREMENT PLAN

To achieve the objective of a reliable resource assessment, the wind resource database developed in this activity must be highly reliable and accurate and consistent in nature across all sites. The wind data will be collected in a manner consistent with the American Wind Energy Association's *Standard Procedure for Meteorological Measurements at a Potential Wind Turbine Site* and *Recommended Practice for the Siting of Wind Energy Conversion Systems* [25,26].

In order to accurately predict the performance of potential wind energy projects, it is desirable to have data concerning wind speed, direction, and wind shear (change in speed with height above the ground). For nine of the proposed wind monitoring stations, a 90 ft mast tower with data collection at two heights is recommended. Cup anemometers (one at each height) and a single wind vane will be used. A 30 ft tower is recommended for Kaneohe.

FIELD MEASUREMENT EQUIPMENT SELECTION

In order to determine the most appropriate equipment to use for the monitoring program, quotes and product literature were obtained and discussed with well-known manufacturers. Criteria used to decide on the recommended equipment included costs, accuracy, reliability, durability, ease of use, and support from the manufacturer. As a result of this analysis, NRG9200-21 data loggers with two NRG40C calibrated anemometers and one NRG200P direction vane are recommended for use in this project. The data logger and sensors will be mounted on NRG90TT 90 ft or 30 ft tall towers. Hourly average wind speed and most frequent direction will be reported with a resolution of 0.1 mph and 1 direction sector. Data sampling accuracy are +1 -0 mph and ±4 degrees.

FIELD EQUIPMENT TESTING AND INITIAL CALIBRATION

The equipment will be delivered to Hawaii calibrated and ready for installation. Before installation, the sensors will be inspected to verify that they are in proper functioning condition.

FIELD EQUIPMENT INSTALLATION

Siting

Towers will be located at sites representative of the overall resource of the potential project site and consider factors such as prevailing wind direction and surrounding land forms. Measurements will be taken in an open area, free from heavy vegetation and structures. Nominal anemometer heights will nearly be 30 and 90 ft (actual anemometer heights will be measured and recorded).

Installation

Meteorological measurement sites will be installed according to the manufacturer's instructions regarding field installation, including grounding, sensor wire shielding, and weatherproofing the installation. Particular attention should be paid to ensure that the guy wire anchors are appropriate for the soil conditions. An anemometer is mounted at the top, with an associated wind vane oriented so that a "North" indication of the wind vane indicates true-north rather than magnetic north. The 30 ft anemometer will be mounted on a cross-arm attached to the tower at a distance of at least six tower diameters from the tower into the prevailing trade wind direction. The data logger will be attached to the tower at a height that reduces the likelihood of damage from horses or grazing animals, and will be kept locked at all times that it is left unattended. Barbed wire will be used on the guy wires in grazing areas to dissuade cattle or horses from disturbing the equipment.

FIELD EQUIPMENT MAINTENANCE

During each site visit, the following activities will be performed, and information will be recorded on a Maintenance Report Post Card that will be mailed to RLA:

- Record the date, time, and the name of the person conducting the site visit, and the site visited.
- Visually inspect the physical condition of the entire installation and of the general functioning of the sensors for proper appearance and operation. Record/correct any irregularities.
- Visually inspect the tower assembly, including the guy wire tensions, the vertical trueness of the mast, and the condition of the grounding system. Record/correct any irregularities.
- Check the battery voltage. Replace the batteries as needed, per the logger manufacturer's instructions. Record any changes.
- Check the data logger operation according to the manufacturer's instructions.
- Document any other observations and actions taken under the "Comments" portion.

Site maintenance frequency will initially be at bi-weekly intervals. Because the necessary site maintenance frequency depends on site-specific conditions, data from each site inspection will be carefully analyzed to see if less frequent visits can be made without loss of accuracy. In no event will site maintenance visits be made less frequently than once per month.

DATA COLLECTION AND QUALITY VERIFICATION

Data will be collected from site locations on a monthly basis. A back-up copy of the data chip will be made at the time of data collection. Both chips will be labeled with the monitoring site name, date, and time of collection. One chip will be mailed to RLA. The backup chip will be stored until the next month when it will again be used to back-up the data. In the event that the first chip is lost or damaged, there is a backup.

After receiving the chip at RLA, data will be transferred to an IBM computer in ASCII format. The data will be examined for completeness and reasonableness. Any irregularities will be reported to site personnel immediately, whereupon a site inspection and maintenance visit will be performed in order to ensure a high rate of data recovery and high data quality.

High correlation of wind speeds is expected from the two anemometers on each wind monitoring station. In the event that the monthly record from one of the anemometers experiences a low data recovery rate, accurate estimates should be obtained through extrapolation of data from the other anemometer. The use of two anemometers provides redundancy and ensures accuracy as well as providing wind shear information.

DATA PROCESSING

On a monthly basis, RLA personnel will produce data summaries using NRG's EEREADER software. These summaries will include hourly average wind speeds, wind speed distribution, tabulated wind rose, diurnal wind speed variation, information about turbulence, maximum peak gust, and sustained wind speeds.

SOLAR RESOURCE MEASUREMENT PLAN

The goal of this solar resource measurement effort is to develop a high-quality database of solar irradiance measurements at selected sites over a one year period. In a later project phase, these data will be used as the basis on which to compare and assess the potential of certain renewable energy technologies in different areas of the State. In order to predict station performance, data need to be collected for both direct normal (broad band) irradiance (DNI), and global horizontal diffuse (broad band) irradiance (DHI), as well as the more commonly and easily measured total global horizontal (broad band) irradiance (GHI).

To achieve the objective of a reliable technology assessment, the solar radiation database developed in this activity must be highly reliable and accurate and consistent in its nature across all sites. The resulting data must also be of known measurement quality, and be directly traceable to World Meteorological Organization (WMO) radiometric reference standards.

These goals will be met through adherence to the following practices and methods:

FIELD MEASUREMENT EQUIPMENT SELECTION

Several possible equipment types were evaluated for collecting solar data. It was determined that use of LICOR Model 200S pyranometers, fitted with automated rotating shadow band mechanisms that allow direct measurement of GHI and DHI, with DNI directly and accurately calculated, offered the best option with regards to cost and accuracy. Selected overall measurement systems must achieve a total measurement uncertainty within ±7.5% for all three broad band components: DNI, DHI, and GHI. Achievement of desired measurement uncertainties are possible with this equipment provided that accurate initial calibrations are performed, and proper installation and maintenance procedures are followed.

FIELD EQUIPMENT PROGRAMMING, TESTING, AND INITIAL RADIOMETER CALIBRATION

Campbell Scientific Model CR10 data loggers will be used to read and store sensor scans and control the rotating shadow band mechanisms. The CR10's will be programmed to measure GHI and DHI and compute DNI once per minute, and to store averages of these parameters every 15 minutes. All time references will be made in local standard time.

Upon receipt of the data loggers and rotating shadow band radiometer (RSR) units, the LICOR 200S pyranometers associated with each unit will be calibrated at Augustyn & Company, Inc.'s (ACI) radiometer calibration test facility in Albany, California. This calibration test will employ the continuous shaded component summation calibration technique drawn from techniques defined in ASTM test standards E816-81 and E913-82 as further refined by the staff of the Solar Resource Assessment Project at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. This technique provides direct traceability to WMO radiometric reference standards via ACI's and NREL's reference instruments. The minimum calibration uncertainty achievable by the ACI calibration facility is ±2.2% for DNI measurements, and approximately 3.5% for GHI measurements. New calibration factors will be derived for each of the new LICOR 200S pyranometers to be used in this project as a result of this initial calibration.

FIELD EQUIPMENT INSTALLATION

Siting

Field measurement equipment will be located so as to preclude or minimize full or partial direct beam shading of the radiometers at any time of day or year. Also, siting will minimize blockage of the diffuse sky dome by any adjacent structures, objects, or local airborne (optical) contaminants. A detailed description of the site will be provided in the report that will accompany the final data delivery. This report will document any site features that might have affected the readings.

Installation Procedures and Practices

In addition to strict adherence to all manufacturer's instructions regarding field installation, including grounding, sensor wire shielding, and weatherproofing the installation, particular attention will be paid to ensuring that the equipment will be mounted to a very secure base to avoid the possibility that the sensor will drift out of level during the course of the measurement period.

Field Equipment Maintenance

Periodic site maintenance activities will include:

- Visual inspection of the physical condition of the entire installation and of the general functioning of the rotating mechanism for proper appearance and operation.
- Visual inspection and written notes on the appearance of the sensor surface.
- Cleaning the sensor surface with distilled or deionized water and a soft cloth or tissue.
- Completing and mailing a Maintenance Report Post Card, documenting observations and date and time of cleaning.

Site maintenance frequency will initially be at one week intervals. Because the necessary site maintenance frequency depends on site-specific conditions, data from each site inspection will be carefully analyzed to see if less frequent visits can be made while maintaining our overall goal for measurement uncertainty. In no event will site maintenance visits be made less frequently than once per month.

Data Collection and Quality Verification

Each monitoring station will be equipped with a telephone modem and phone line. Data will be retrieved automatically each night from each site by a computer in ACI's Albany, California, office. The retrieved data files will then be run through ACI's Data Verification Systems (DVS), which will perform a variety of tests to assess data quality and proper functioning of the site units. Included in these tests will be the two- and three-component solar irradiance data quality control test devised by NREL called "SERI QC." DVS will assign a multi-component data quality flag to each data value retrieved, indicating both the results of tests made and the exact nature of any modification made to a data value. Data will be delivered both with and without data quality flags as generated by DVS.

Once DVS has completed its automatic data quality screening, ACI personnel will review the results, and immediately contact site maintenance personnel if any remedial action is necessary. Daily, automated data collection and quality assessment will therefore minimize the total amount of missing or lost data.

Data Summarization and Delivery

On a monthly basis, ACI personnel will produce data summaries using DVS. These will include daily totals and maximums for each irradiance parameter for each day of the month. Data for all sites will be delivered on diskette on a quarterly basis in ASCII files in MSDOS format. For each site, two files will be delivered, one will contain both the data and the associated data quality flags assigned by DVS, while the second file will contain the data without the flags.

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11. General information and discussions with PICHTR personnel.

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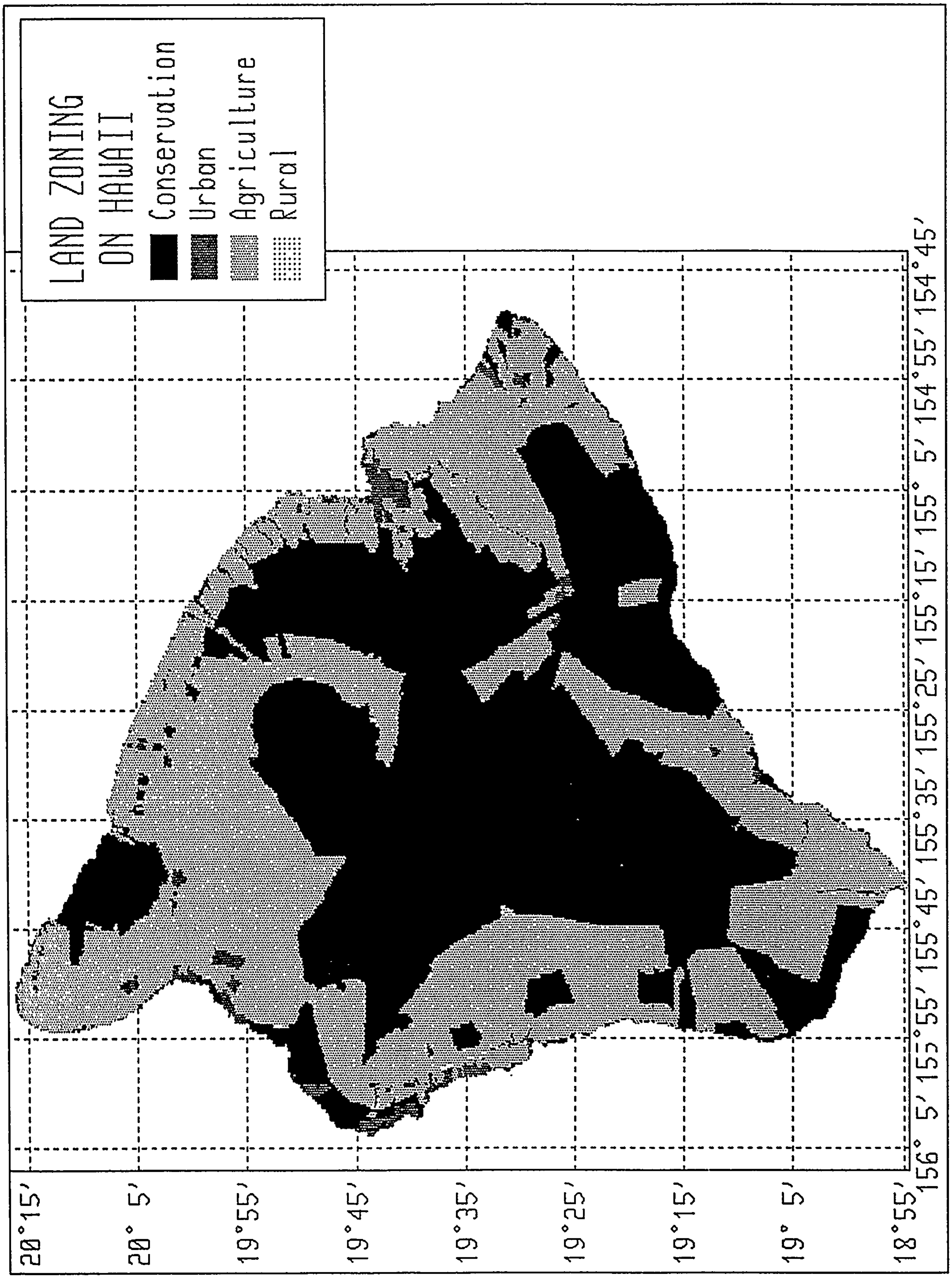
26. Recommended Practice for the siting of Wind Energy Conversion Systems (AWEA 8.2 - 1993)

APPENDIX A

PRELIMINARY LAND ZONING MAPS


LAND ZONING
ON HAWAII
Conservation
Urban
Agriculture
Rural
20°15'
20° 5'
19°55'
19°45'
19°35'
19°25'
19°15'
19° 5'
18°55'
156°
5'
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155°45'
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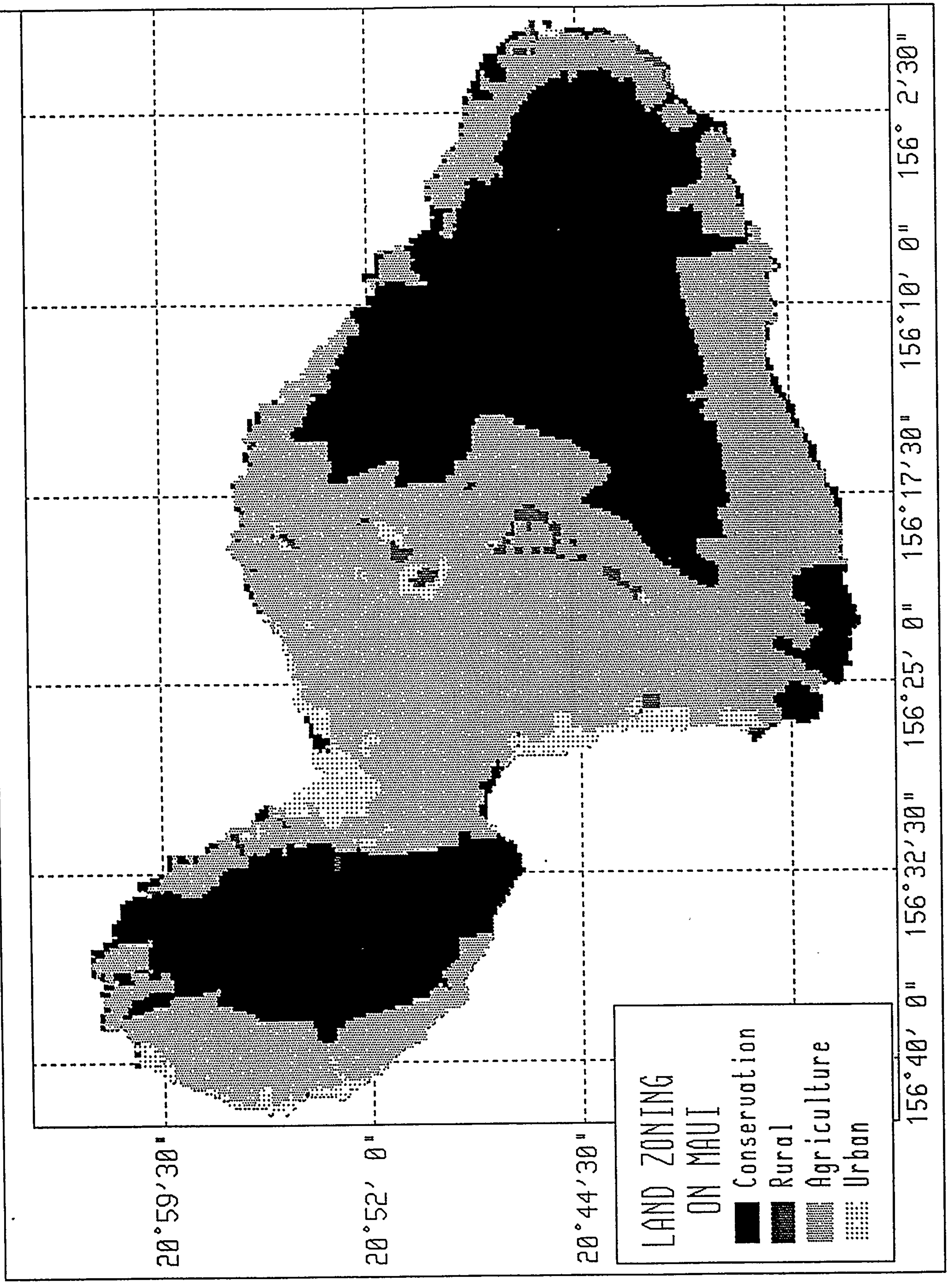
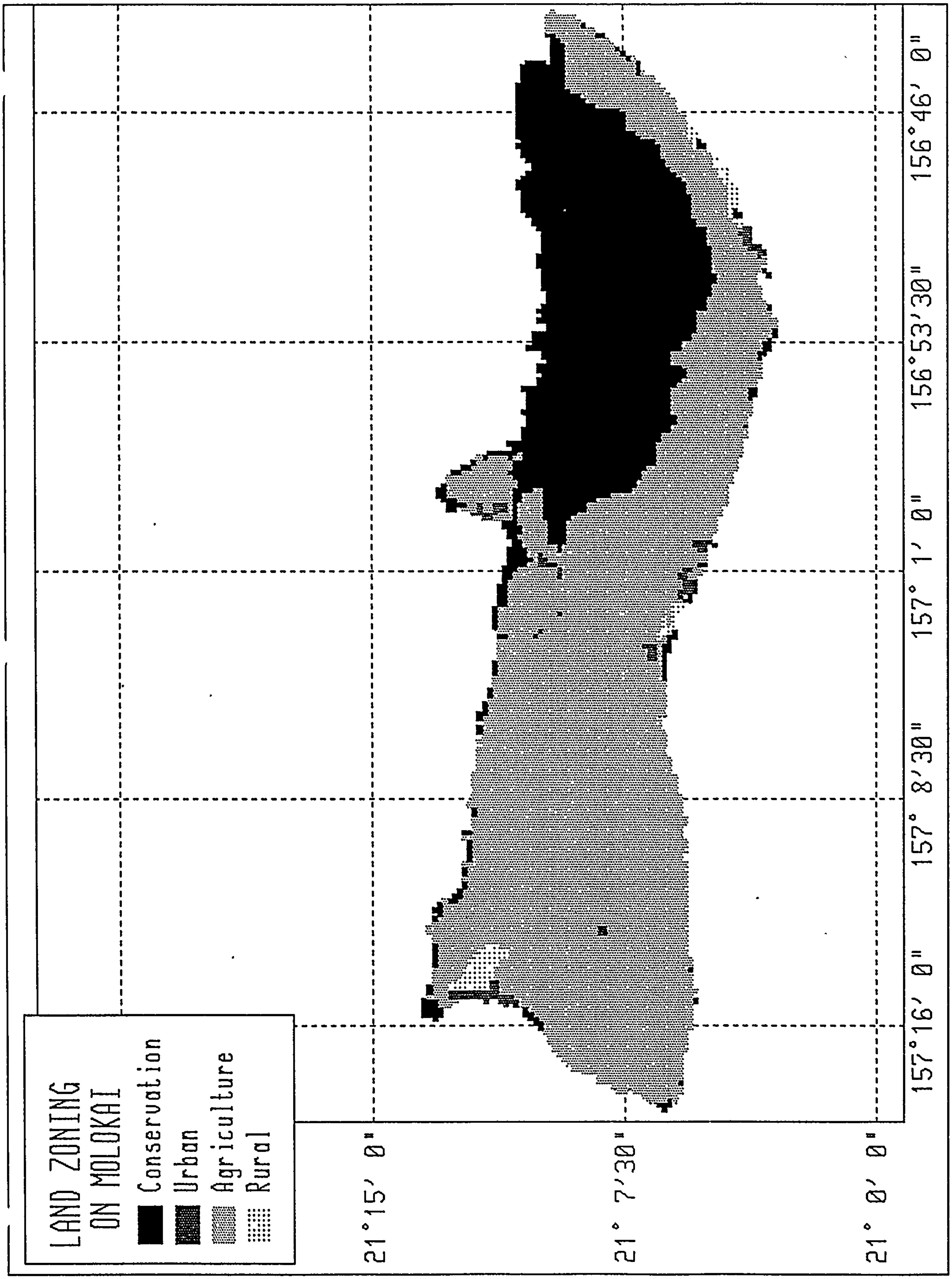
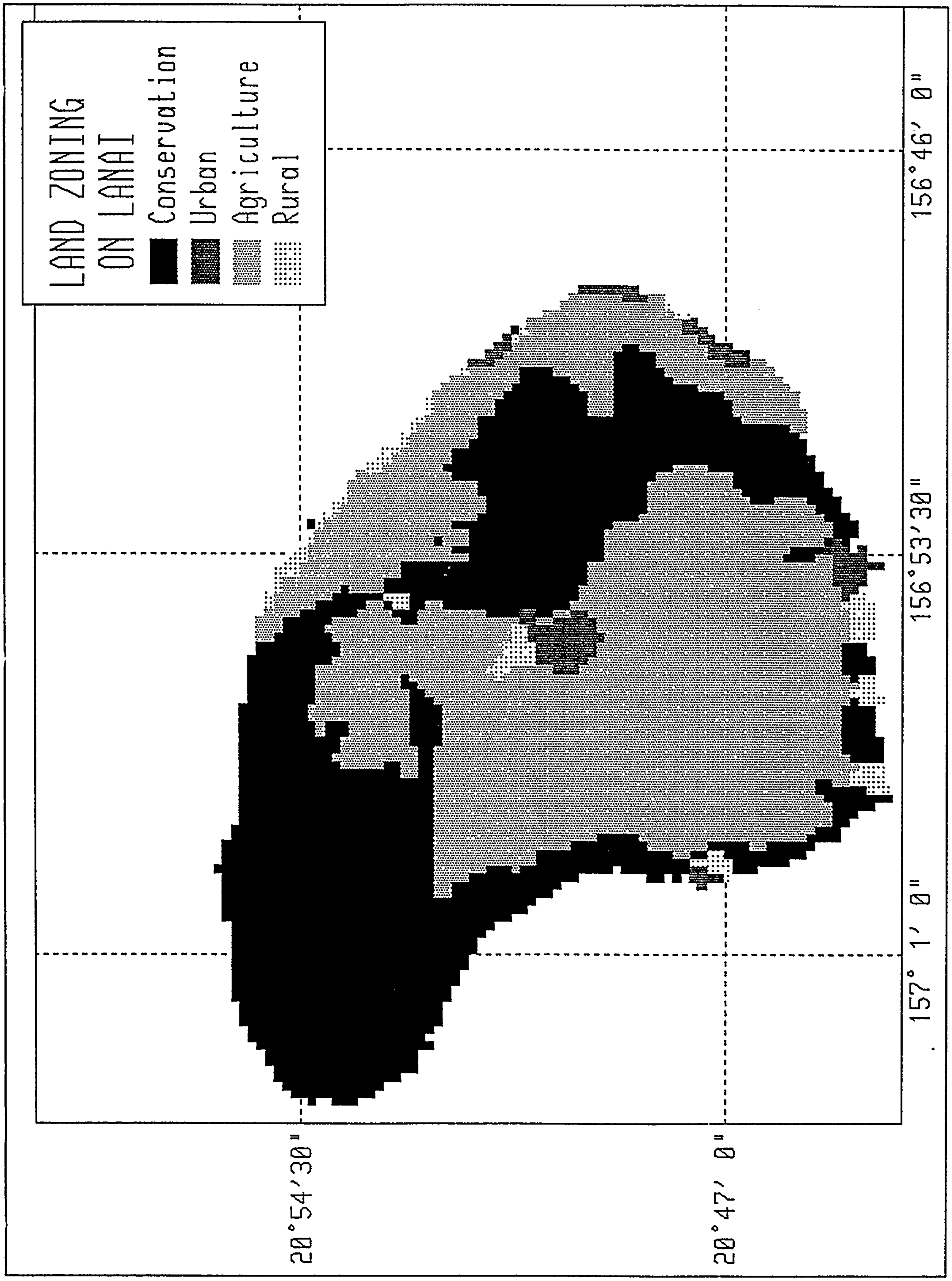
154°55'
154°45'


LAND ZONING
ON MAUI
Conservation
Rural
Agriculture
Urban
20°59'30"
20°52' 0"
20°44'30"
156° 2'30"
156°10' 0"
156°17'30"
156°25' 0"
156°32'30"
156°40' 0"


LAND ZONING
ON MOLOKAI
Conservation
Urban
Agriculture
Rural
21°15' 0"
21° 7'30"
21° 0' 0"
157°16' 0"
157° 8'30"
157° 1' 0"
156°53'30"
156°46' 0"


LAND ZONING
ON LANAI
Conservation
Urban
Agriculture
Rural
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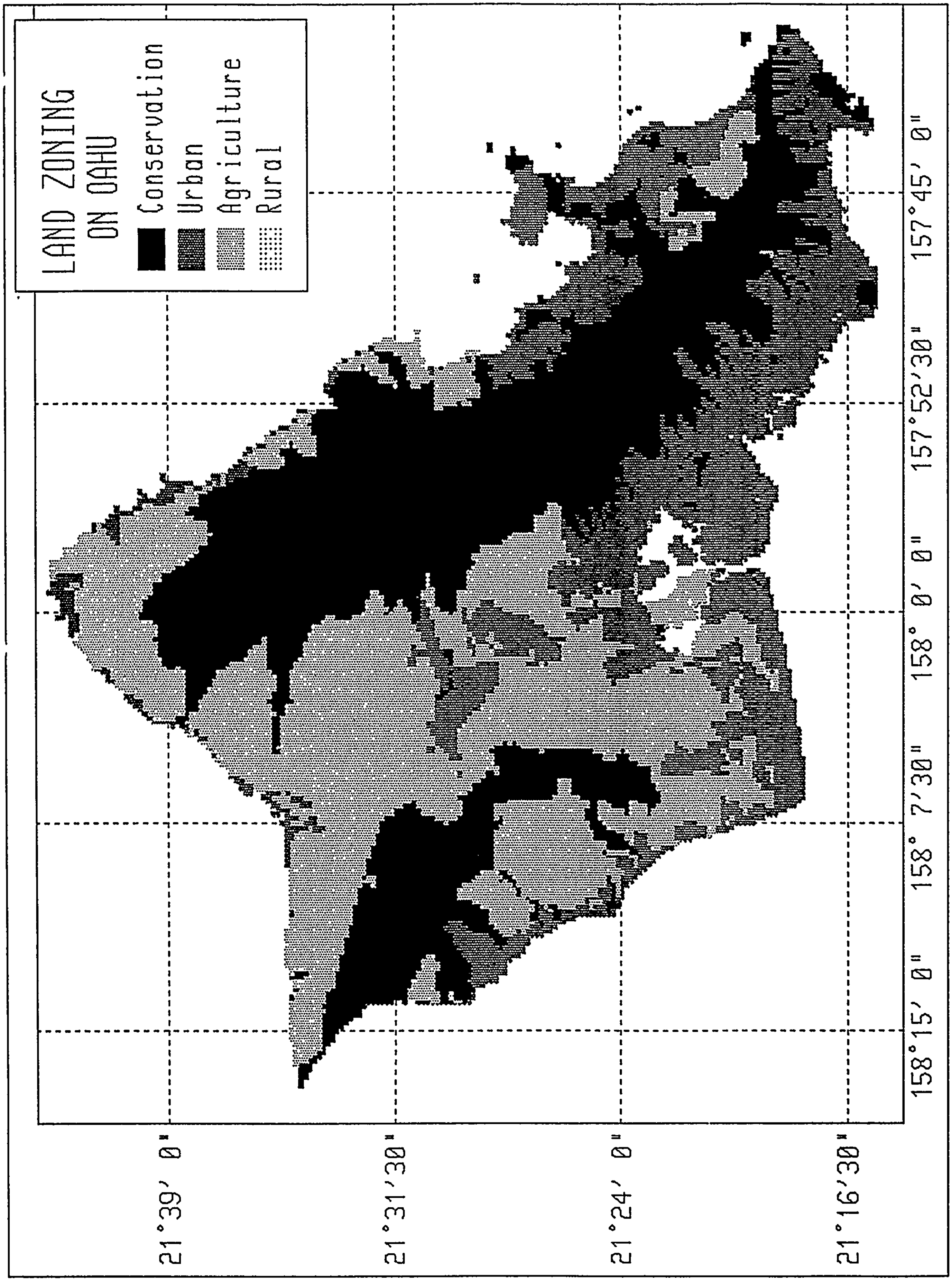
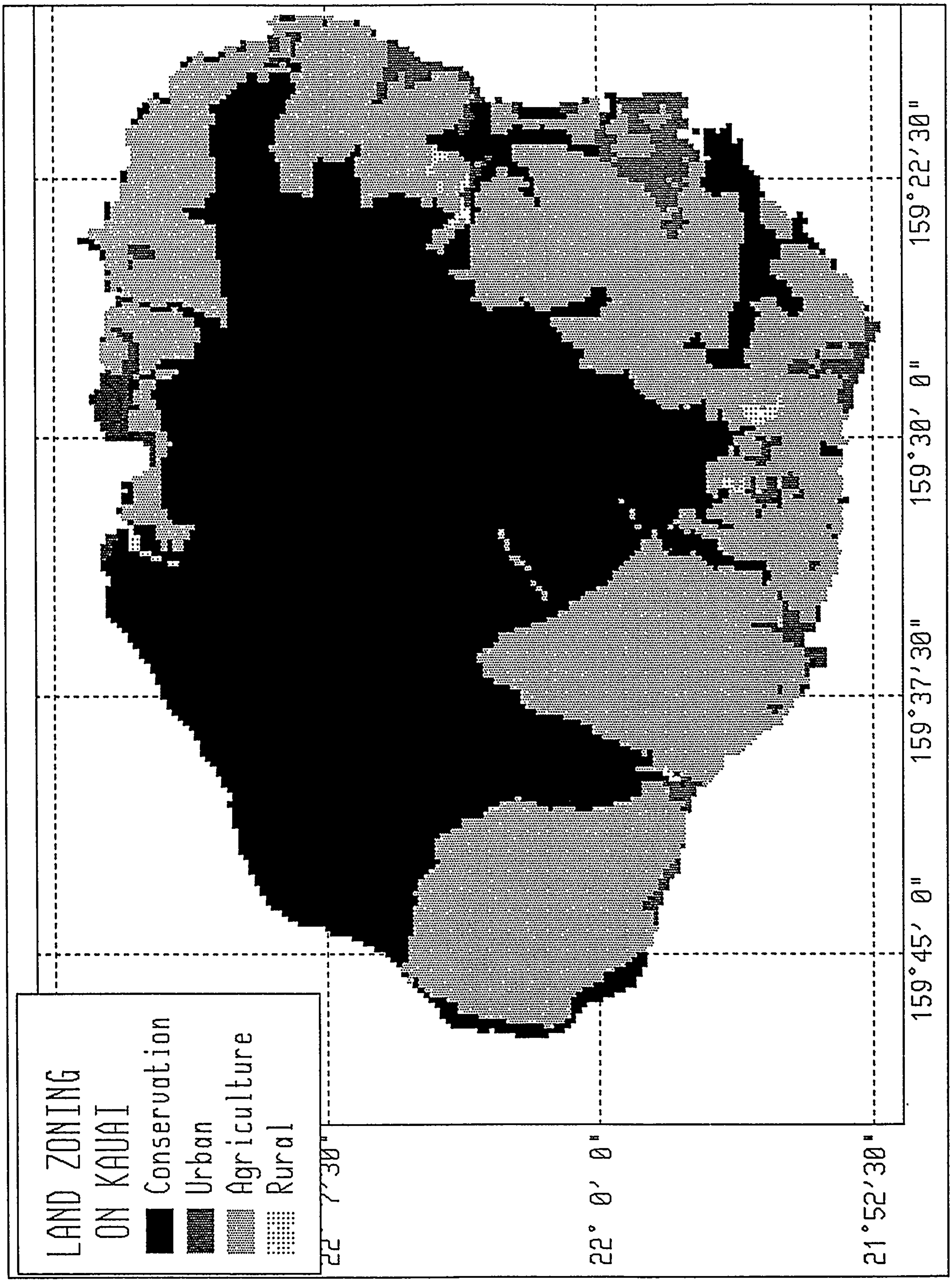
156°53'30"
157° 1' 0"
20°54'30"
20°47' 0"

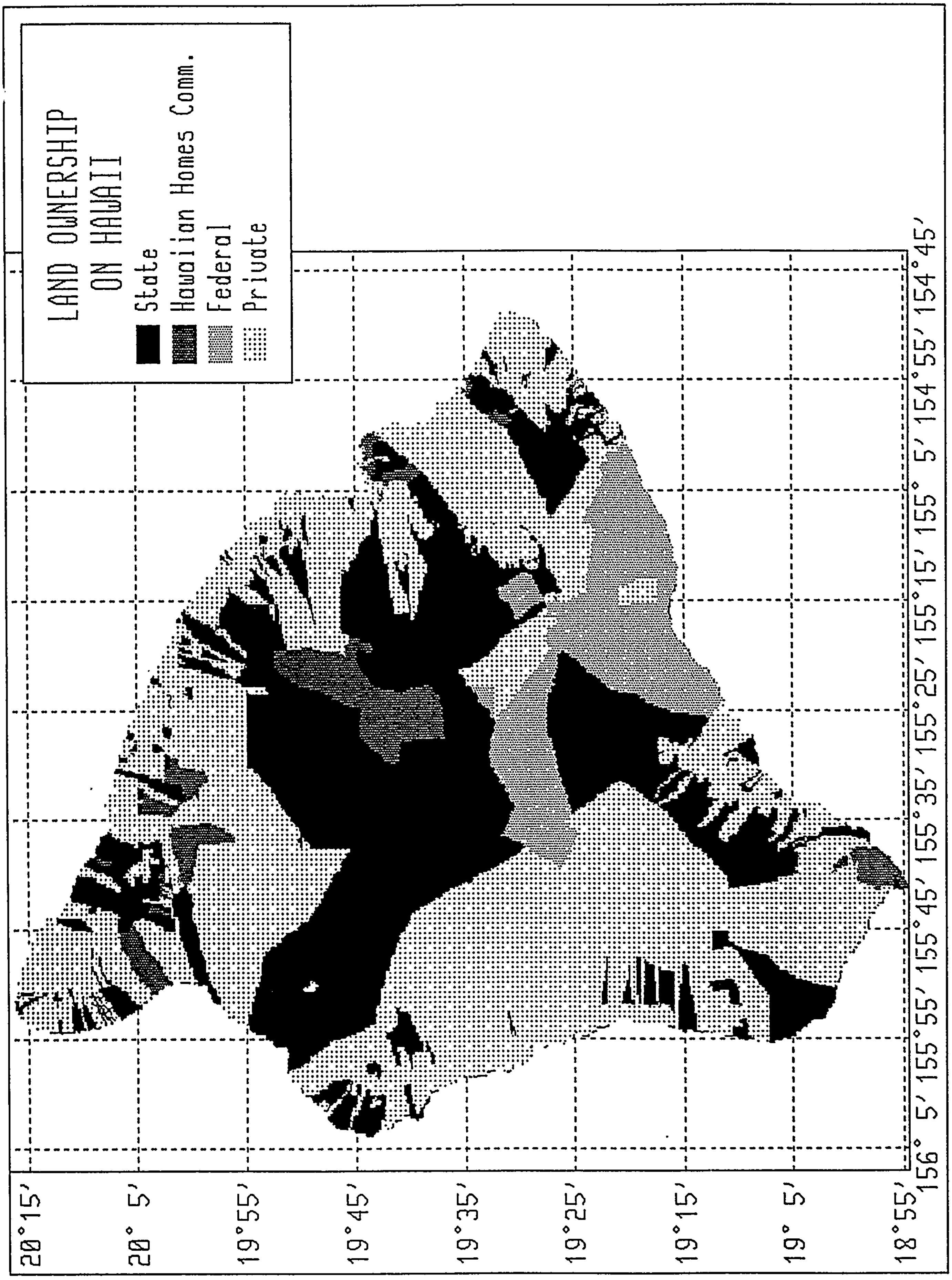

LAND ZONING ON OAHU
Conservation
Urban
Agriculture
Rural
157°45′ 0"
157°52′30"
158° 0′ 0"
158° 7′30"
158°15′ 0"
21°39′ 0"
21°31′30"
21°24′ 0"
21°16′30"



LAND ZONING
ON KAUAI
Conservation
Urban
Agriculture
Rural
22° 7'30"
22° 0' 0"
21°52'30"
159°45' 0"
159°37'30"
159°30' 0"
159°22'30"

APPENDIX B

PRELIMINARY LAND OWNERSHIP MAPS


LAND OWNERSHIP
ON HAWAII
State
Hawaiian Homes Comm.
Federal
Private
20°15'
20° 5'
19°55'
19°45'
19°35'
19°25'
19°15'
19° 5'
18°55'
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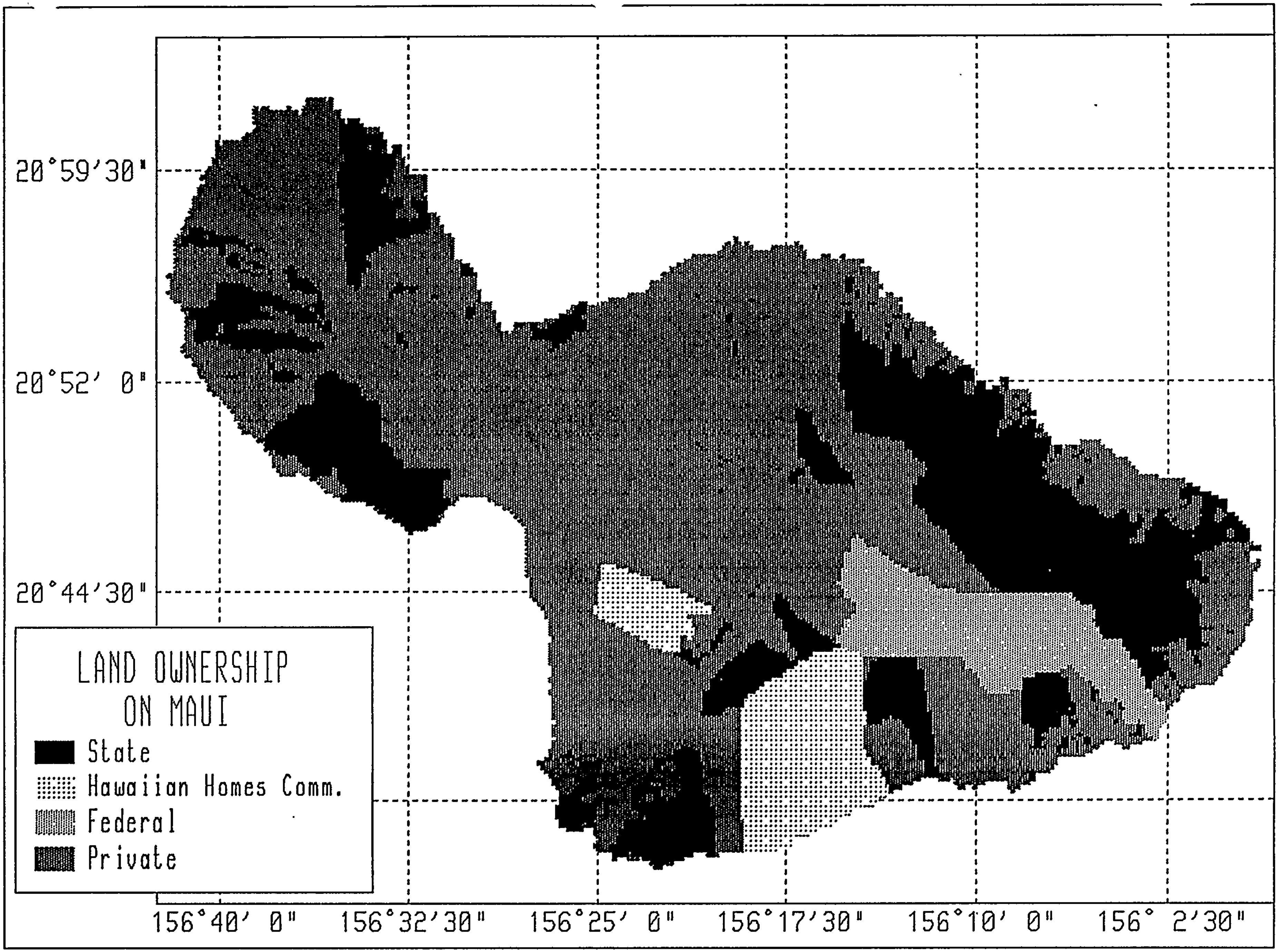
154°55'
154°45'


LAND OWNERSHIP
ON MAUI
State
Hawaiian Homes Comm.
Federal
Private
20°59'30"
20°52' 0"
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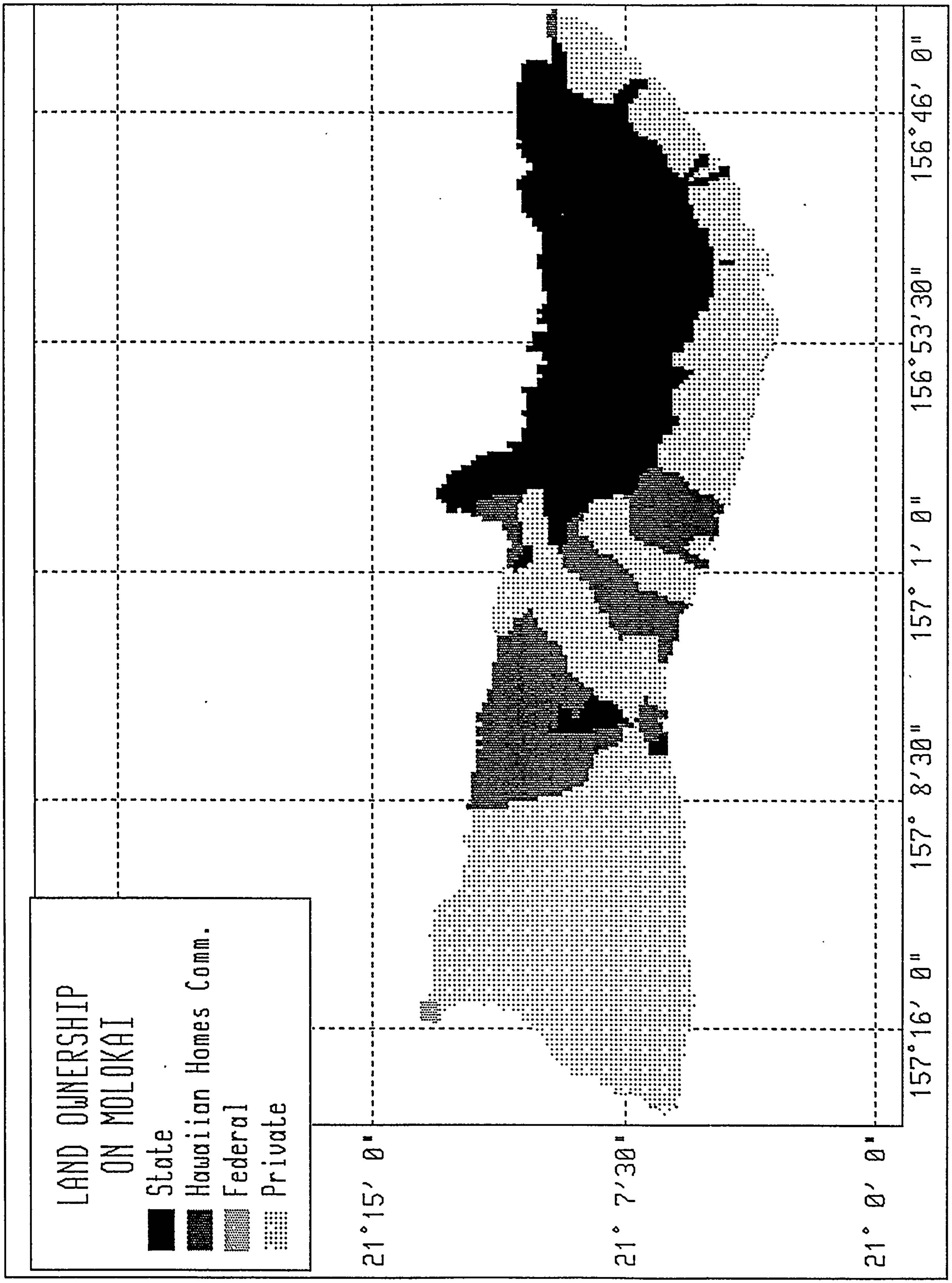
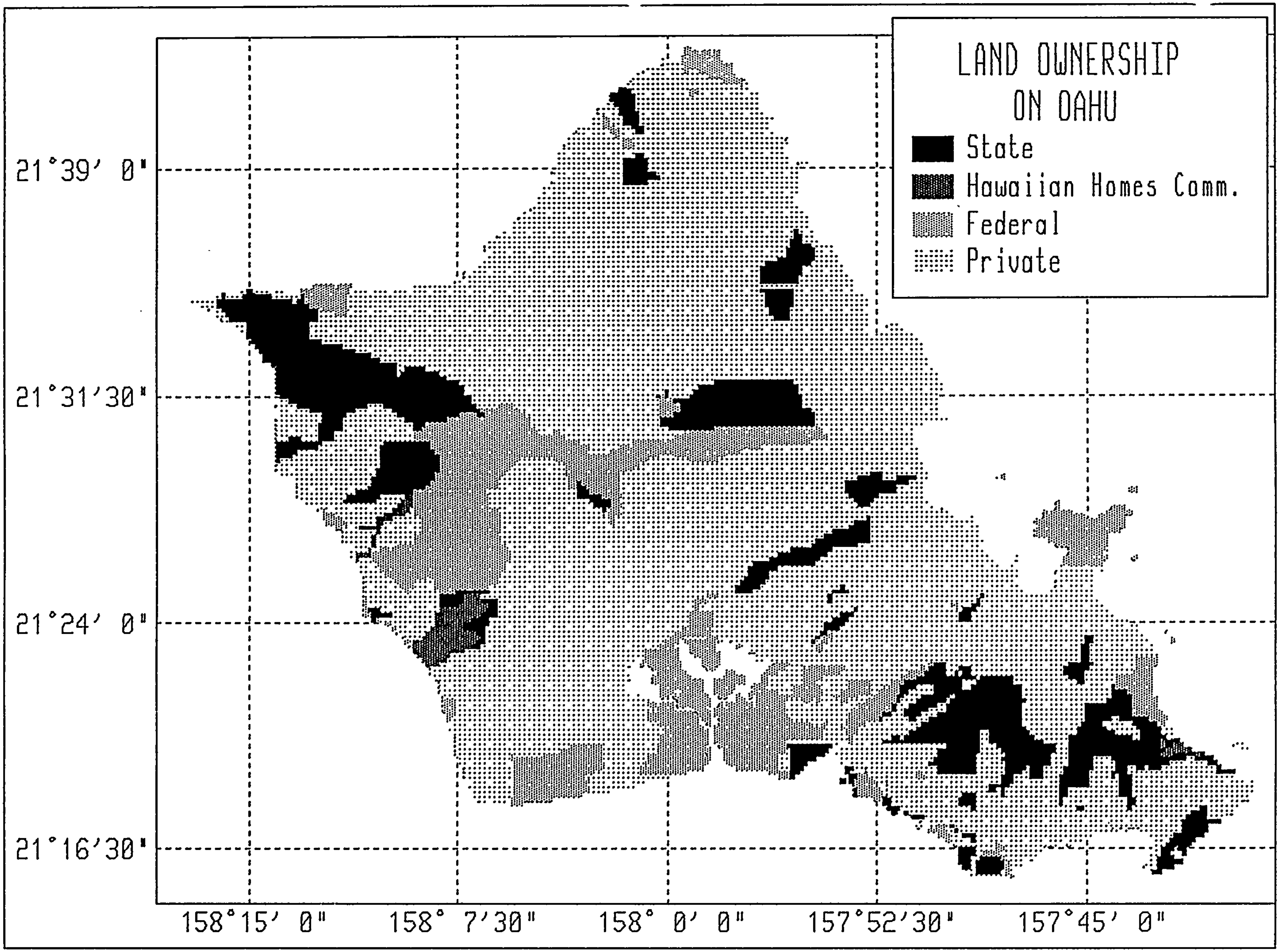
156°40' 0"
156°32'30"
156°25' 0"
156°17'30"
156°10' 0"
156° 2'30"


LAND OWNERSHIP
ON MOLOKAI
State
Hawaiian Homes Comm.
Federal
Private
21°15' 0"
21° 7'30"
21° 0' 0"
157°16' 0"
157° 8'30"
157° 1' 0"
156°53'30"
156°46' 0"


LAND OWNERSHIP
ON OAHU
State
Hawaiian Homes Comm.
Federal
Private
21°39' 0"
21°31'30"
21°24' 0"
21°16'30"
158°15' 0"
158° 7'30"
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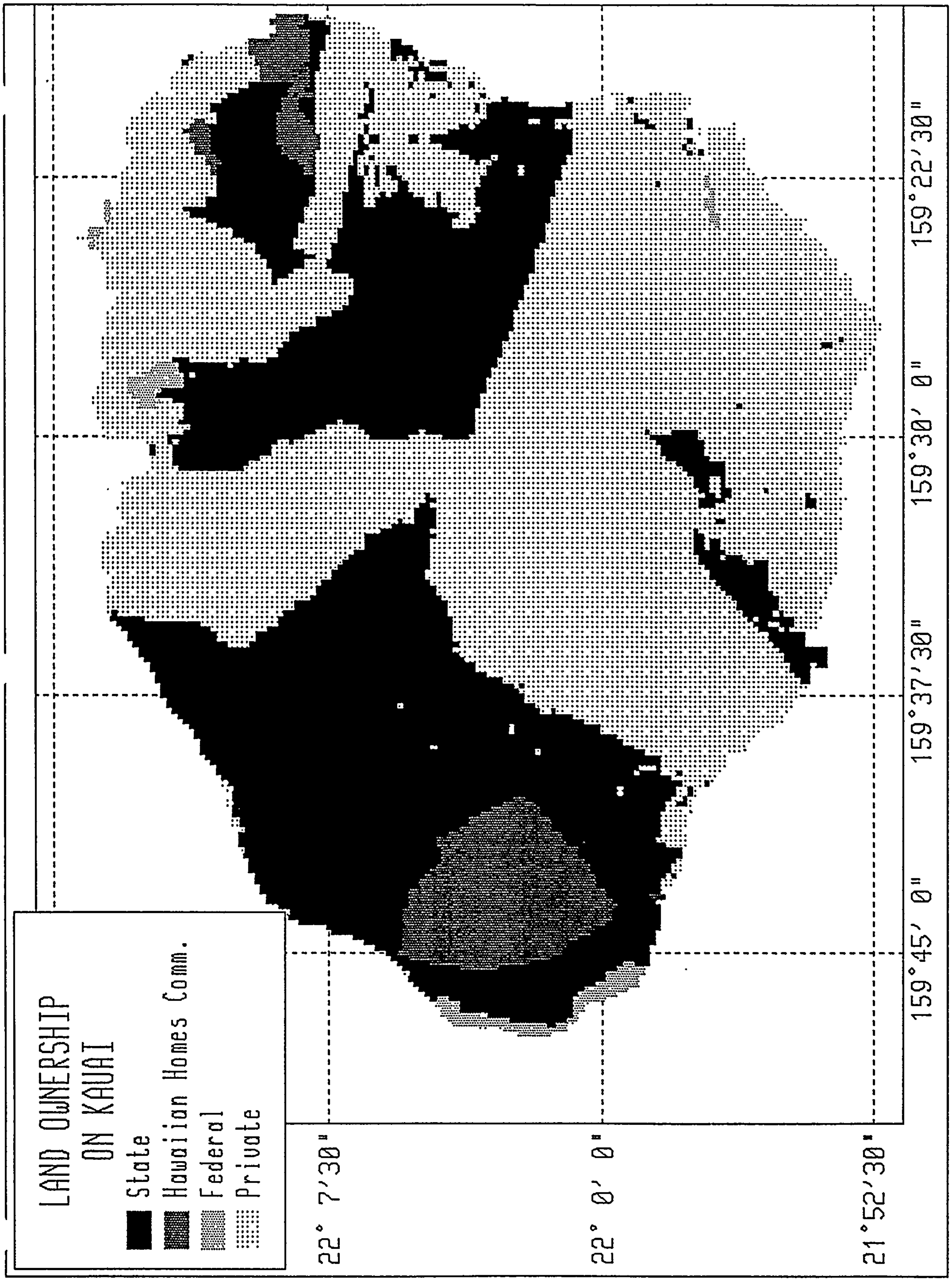
157°52'30"
157°45' 0"

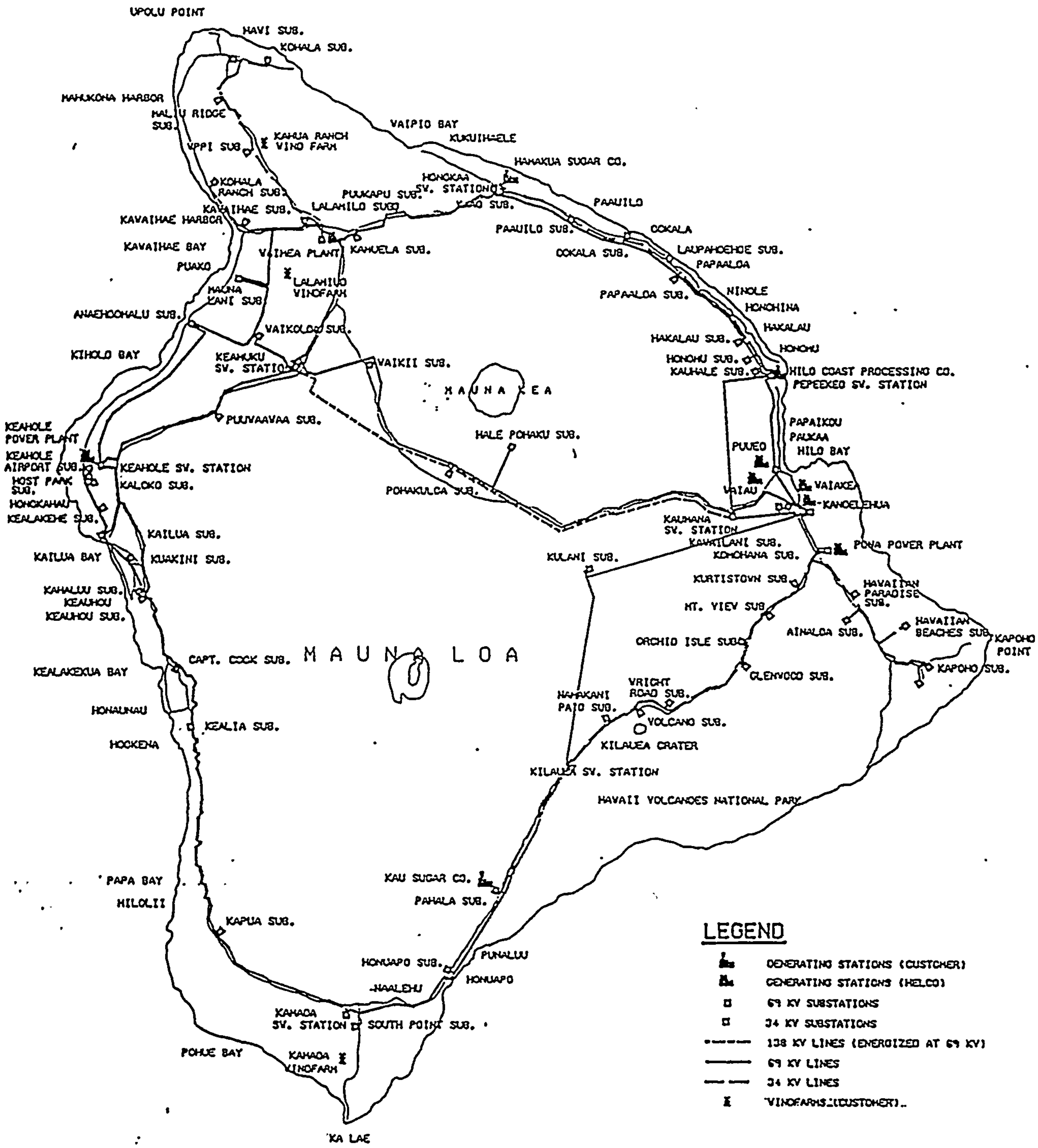


LAND OWNERSHIP
ON KAUAI
State
Hawaiian Homes Comm.
Federal
Private
22° 7'30"
22° 0' 0"
21°52'30"
159°45' 0"
159°37'30"
159°30' 0"
159°22'30"

APPENDIX C

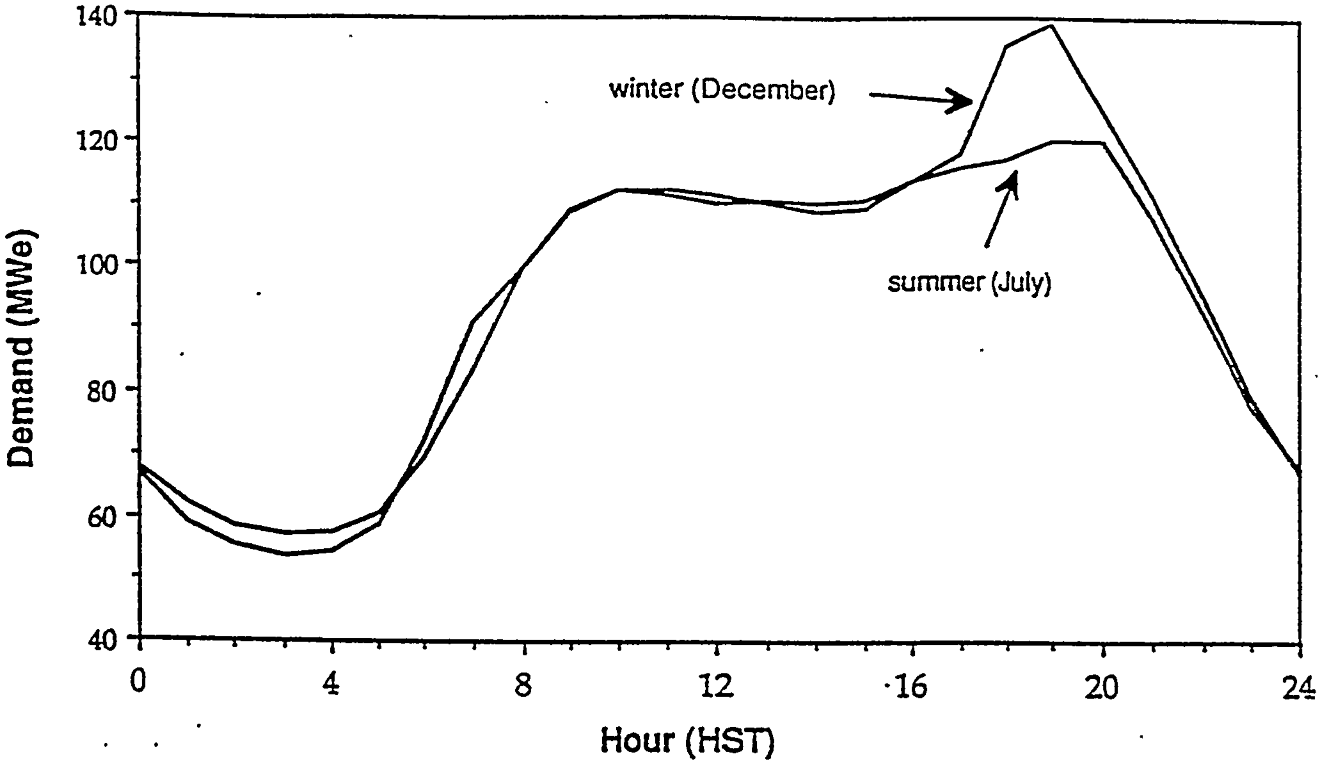
ELECTRIC UTILITY INFORMATION

The following appendix contains information concerning the State of Hawaii's electric utilities, including system transmission maps, diurnal load diagrams, graphs of peak monthly demand, and tables describing the utilities' system resource plans.

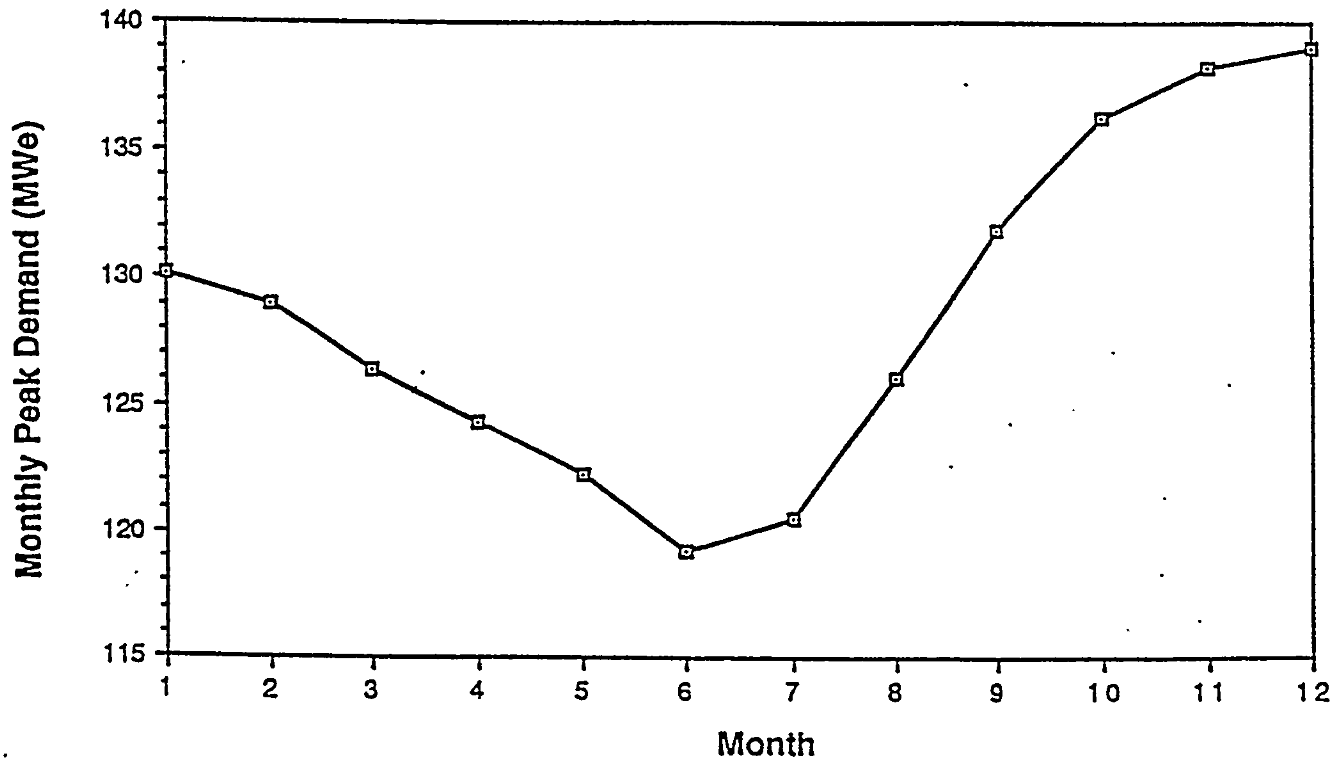


HAWAII ELECTRIC LIGHT CO., INC.
TRANSMISSION LINES

4-93



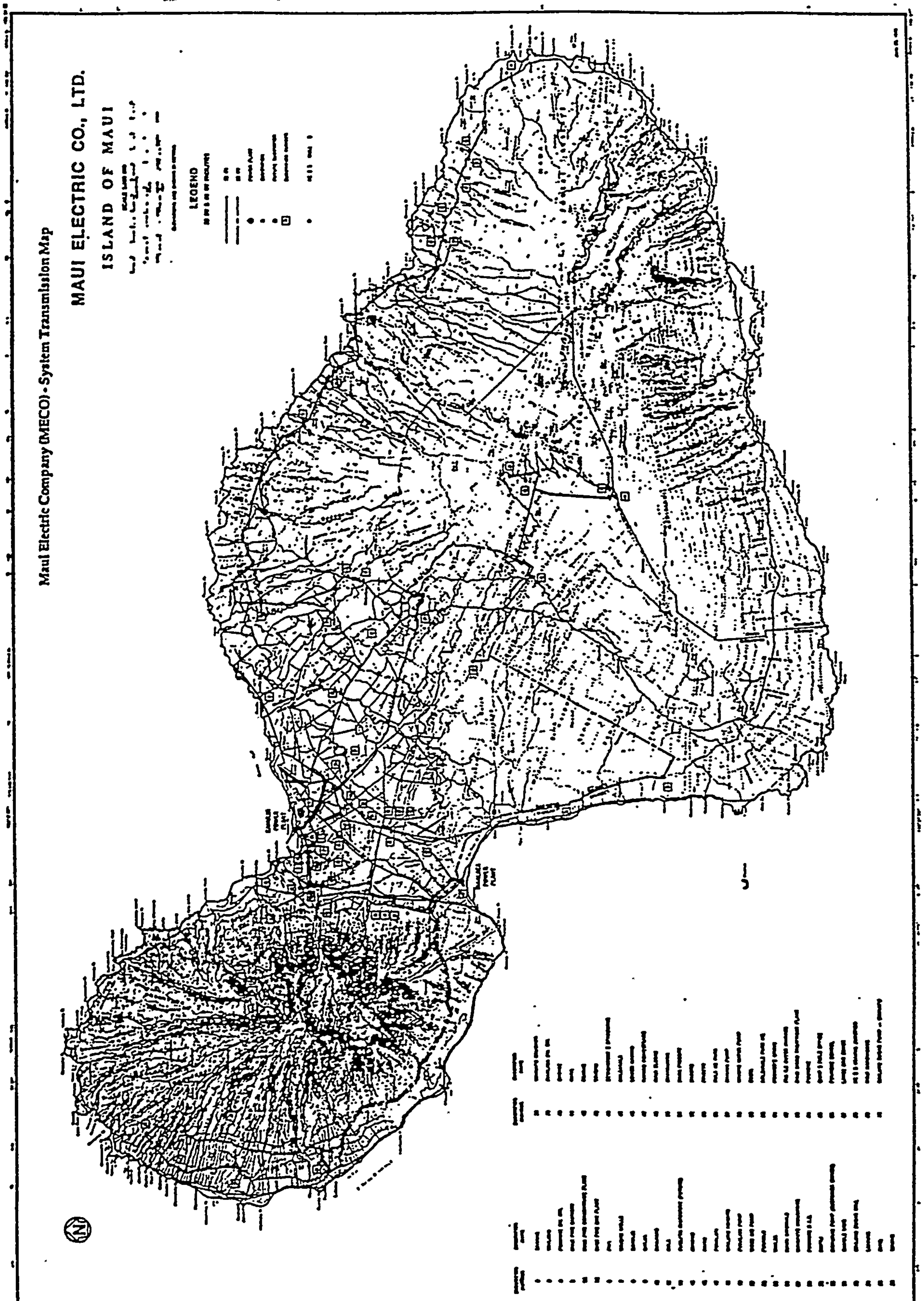
HELCO Typical Daily Load Profiles by Season (based on projected 1990 data)

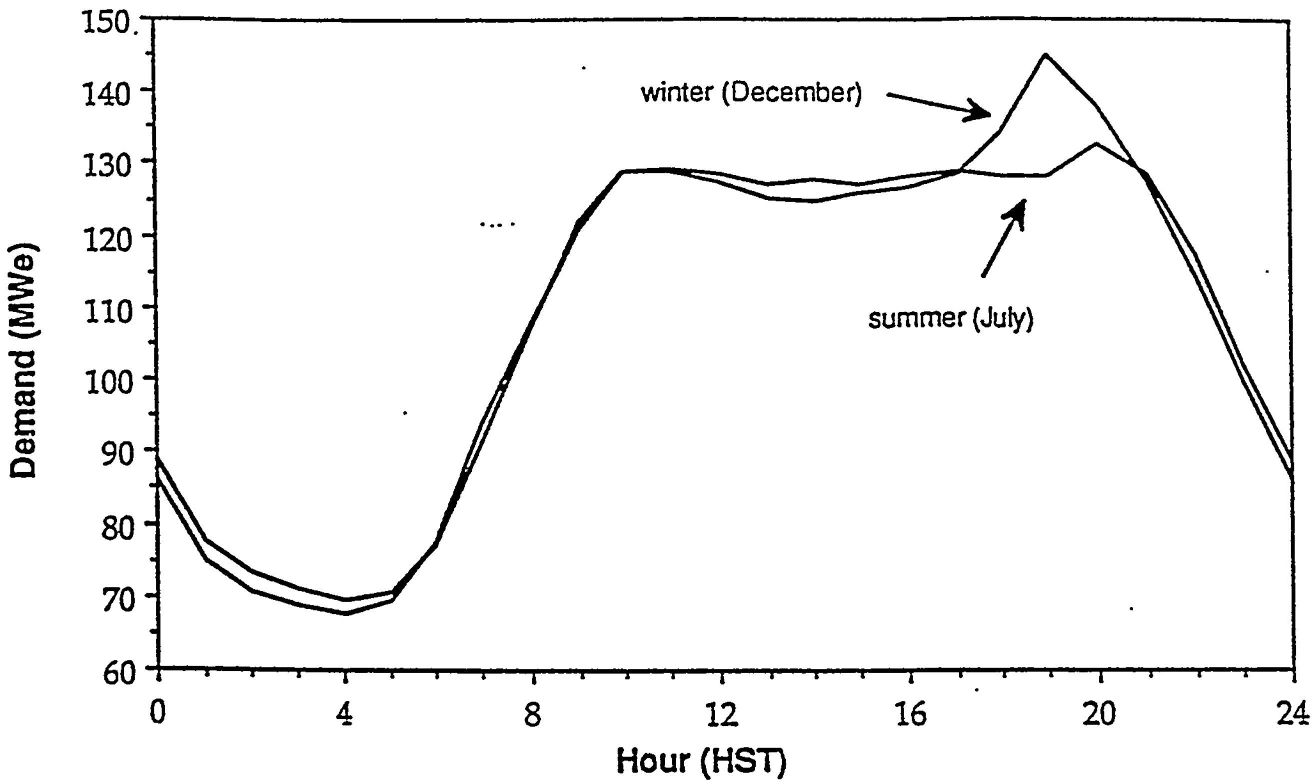


HELCO Peak Demand by Month (based on projected 1990 data)

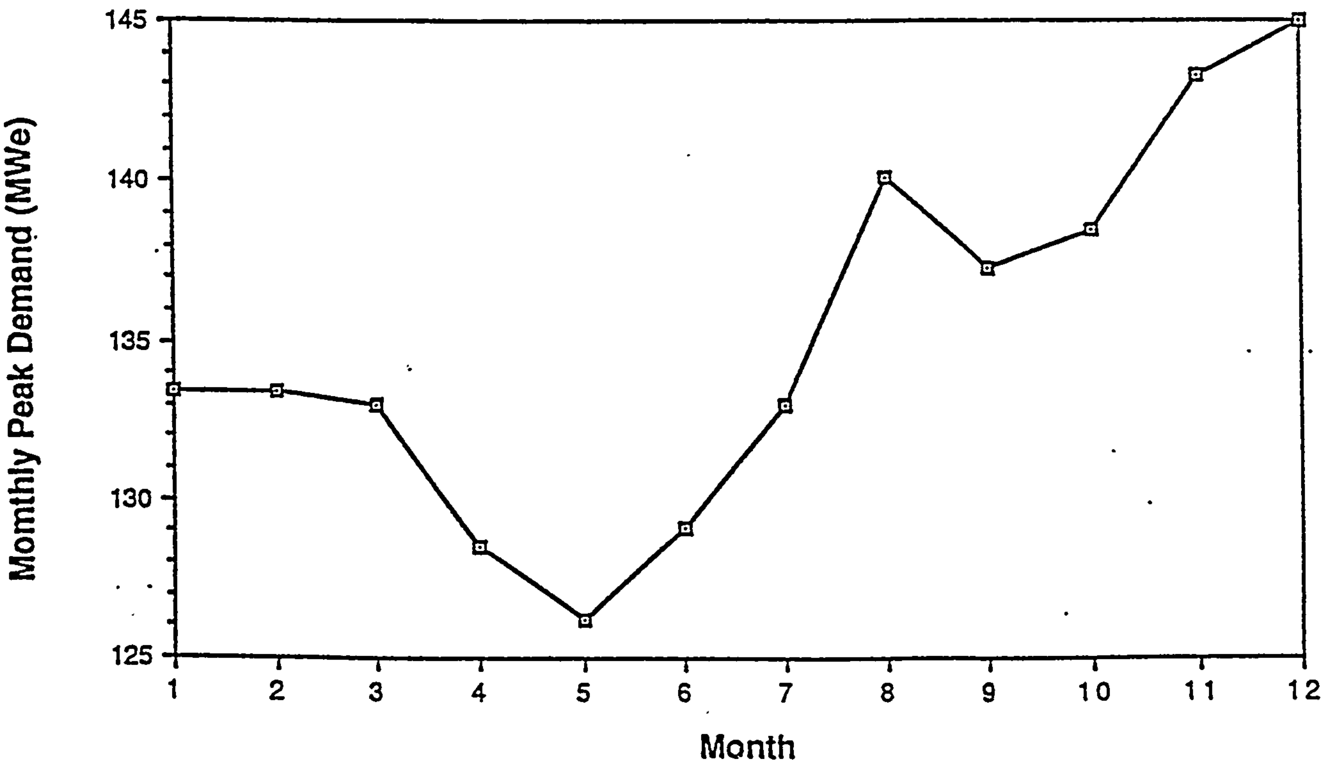
HELCO System Resource Plan

Year	System Peak (MW)	System Capacity (MW)	Reserve Margin (%)	Capacity Modifications Unit	Retired (MW)	Added (MW)
1991	145	161.80	10.8	-	-	-
1992	152	186.80	22.9	PGV Geothermal	-	25.00
		206.80	36.1	Puna CT-3	-	20.00
		197.80	30.1	Kanoelehua CT-1	9	-
1993	163	197.00	20.9	Waimea D-8	0.80	-
		196.10	20.3	Waimea D-9	0.90	-
		195.10	19.7	Waimea D-10	1.00	-
1994	171	215.10	25.8	CT-4	-	20.00
1995	180	211.70	17.6	Shipman 1	3.40	-
		209.70	16.5	Kanoelehua D-11	2.00	-
		206.95	15.0	Waimea D-12	2.27	-
1996	186	226.95	22.0	CT-5	-	20.00
1997	194	215.95	11.3	Waimea D-13, 14 & Kanoelehua D-15, 16	11.00	-
1998	202	231.95	14.8	Convert CT-4 & CT-5 to Combined-cycle-1	-	16
		229.20	13.5	Kanoelehua D-17	2.75	-
1999	209	249.20	19.2	CT-6	-	20.00
		243.70	16.6	Keahole D-18, 19	5.50	-
2000	215	271.70	26.4	Combined-cycle 2 ph 1	-	28.00
		260.70	21.3	Keahole D-20, 21, 22, 23	11.00	-
2001	226	260.70	15.4	-	-	-
2002	234	288.70	23.4	Combined-cycle 2 Ph2	-	28.00
2003	243	288.70	18.8	-	-	-
2004	253	288.70	14.1	-	-	-
2005	262	316.70	20.9	Combined-cycle 3 Ph1	-	28.00
		309.20	18.0	Shipman 3	7.50	-
2006	272	337.20	24.0	Combined-cycle 3 Ph2	-	28.00
2007	283	337.20	19.2	-	-	-
2008	293	329.50	12.5	Shipman 4	7.70	-
2009	304	349.50	15.0	CT-7	-	20.00
2010	316	377.50	19.5	Combined-cycle 4 Ph1	-	28.00
2011	325	377.50	16.2	-	-	-


Maui Electric Company (MECO) - System Transmission Map
MAUI ELECTRIC CO., LTD.
ISLAND OF MAUI
LEGEND



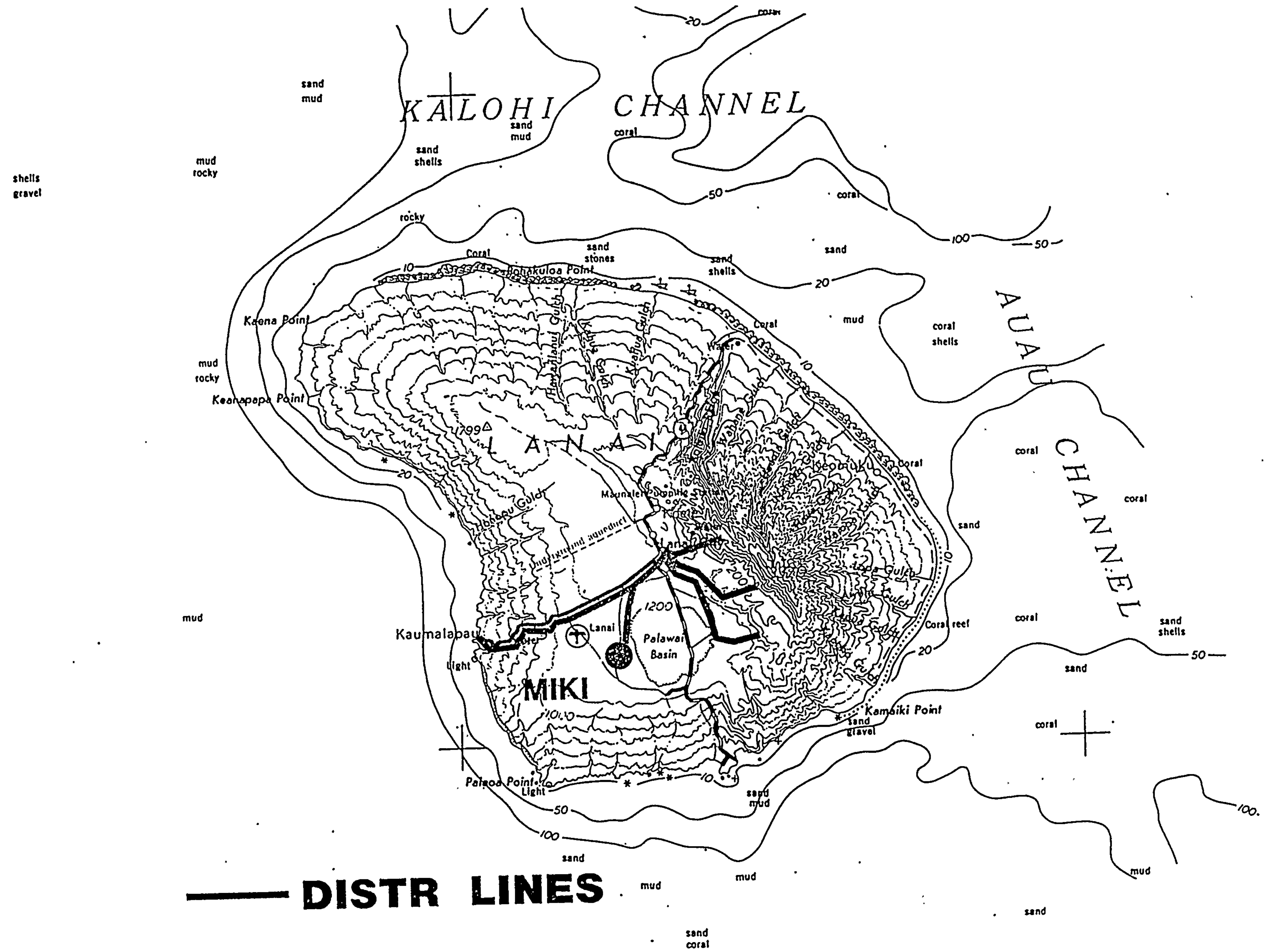
MECO Typical Daily Load Profiles by Season (based on projected 1990 data)



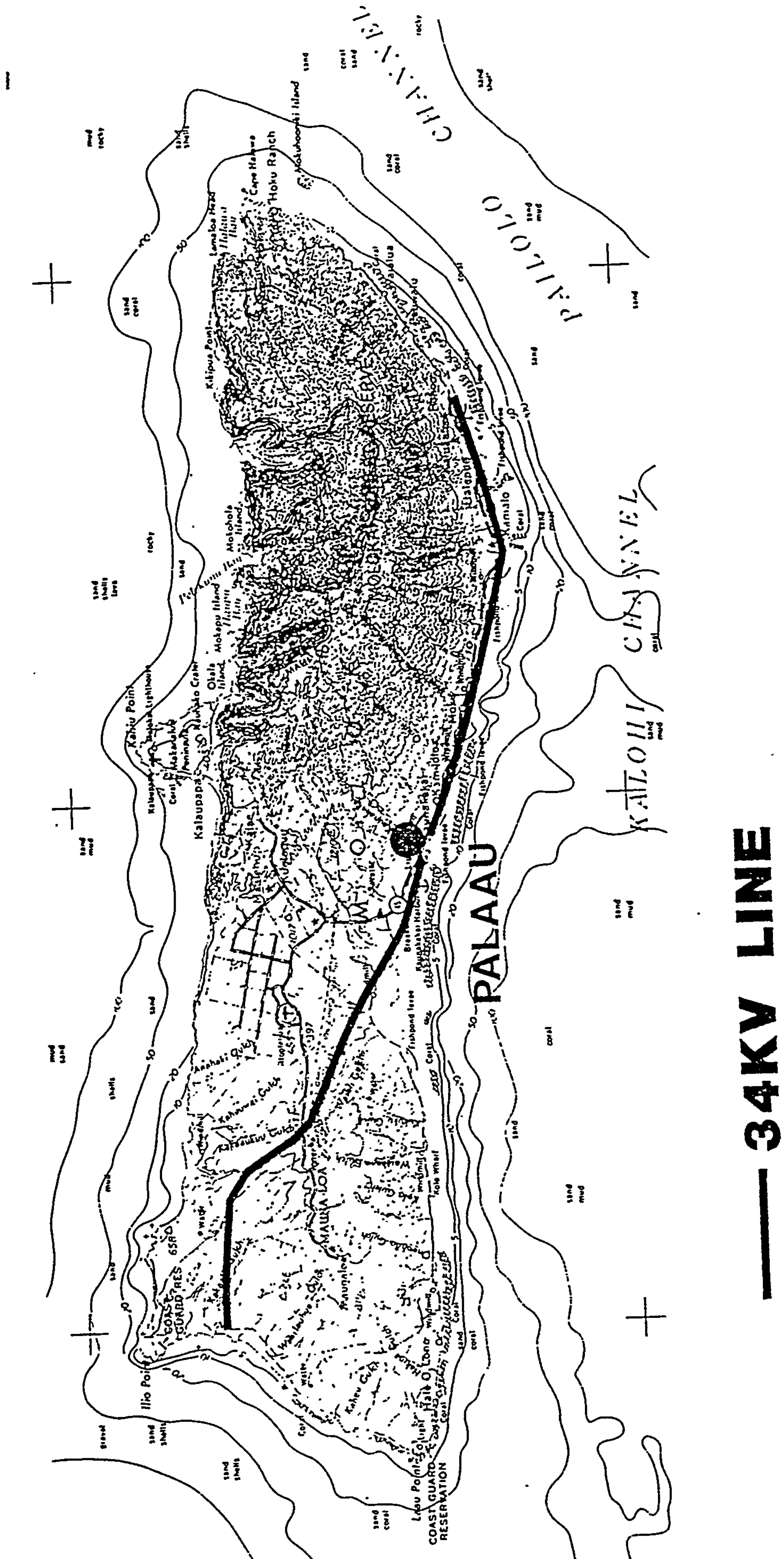
MECO Peak Demand by Month (based on projected 1990 data)

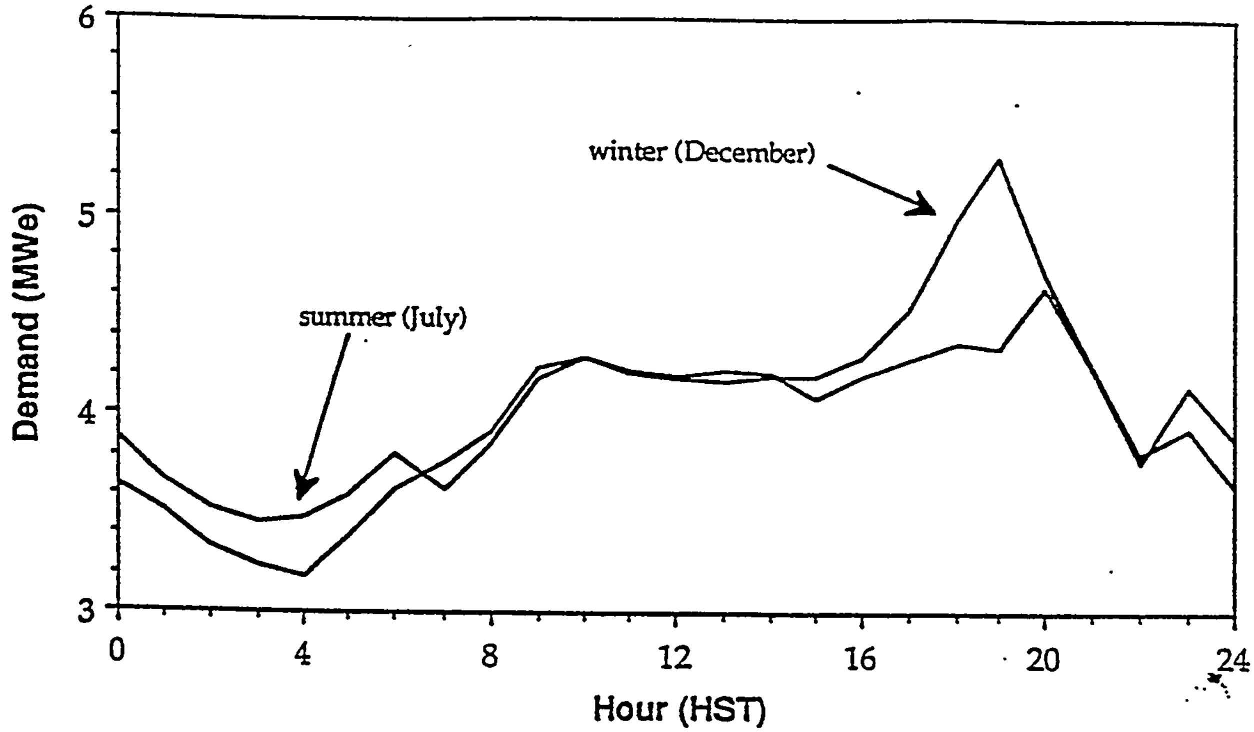
MECO System Resource Plan

Year	System Peak (MW)	System Capacity (MW)	Reserve Margin (%)	Capacity Modifications Unit	Retired (MW)	Added (MW)
1991	149	159.3	6.9	-	-	-
1992	162	179.3	10.7	Maalaea Unit 14	-	20
1993	171	199.3	16.5	Maalaea Unit 16	-	20
		215.3	25.9	Maalaea Unit 15	-	16
1994	179	215.3	20.3	-	-	-
1995	187	235.3	25.8	56MW DTCC #2 Ph 1	-	20
1996	194	232.6	19.9	Maalaea Unit 1	2.75	-
1997	200	252.6	26.3	56MW DTCC #2 Ph 2	-	20
		247.1	23.5	Maalaea Unit 2 & 3	5.5	-
1998	207	263.1	27.1	56MW DTCC #2 Ph 3	-	16
		257.2	24.2	Kahului Unit 1	5.9	-
1999	213	277.2	30.1	Combustion Turbine #3	-	20
		271.2	27.3	Kahului Unit 2	6	-
		255.2	19.8	HC&S 16MW Contract	16	-
2000	220	283.2	28.7	56MW DTCC #3 Ph 1	-	28
2001	228	283.2	24.2	-	-	-
2002	235	311.2	32.4	56MW DTCC #3 Ph 2	-	28
2003	243	298.8	23.0	Maalaea Units 4&5	12.32	-
2004	251	318.8	27.0	Combustions Turbine #4	-	20
		306.1	22.0	Kahului Unit 3	12.7	-
2005	259	334.1	29.0	56MW DTCC #4 Ph 1	-	28
		321.8	24.3	Maalaea Units 6&7	12.32	-
2006	268	321.8	20.1	-	-	-
2007	277	349.8	26.3	56MW DTCC #4 Ph 2	-	28
		343.6	24.1	Maalaea Unit 8	6.16	-
2008	286	337.5	18.0	Maalaea Unit 9	6.16	-
2009	295	357.5	21.2	Combustion Turbine #5	-	20
		343.7	16.5	Maalaea Unit 10	13.75	-
2010	305	371.7	21.9	56MW DTCC #5 Ph1	-	28
		358.0	17.4	Maalaea Unit 11	13.75	-
2011	315	386.0	22.5	56MW DTCC #5 Ph 2	-	28

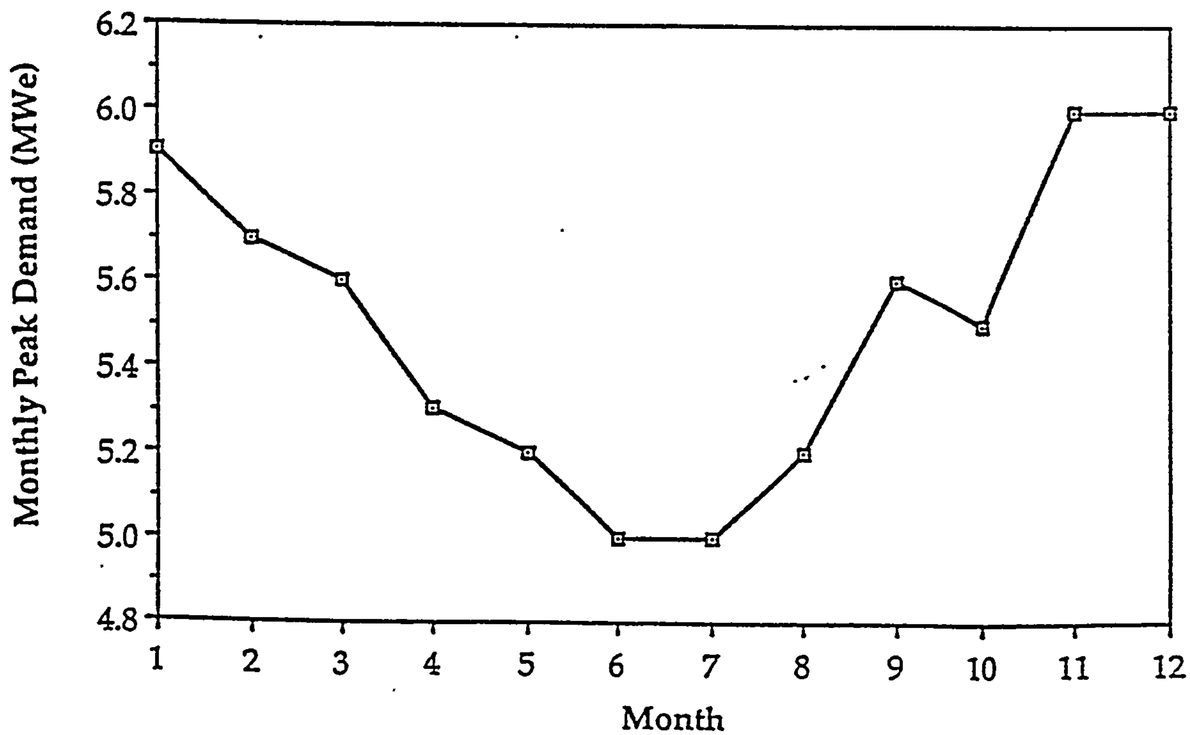


KALOHI CHANNEL
AUAU CHANNEL
LANAI
MIKI
DISTR LINES
Palawai Basin
Lanai
Kaumalapau
Light
Kamaiki Point
Palaoa Point Light
Kaena Point
Keanapapa Point
Honokuloa Point
Hanalilanui Gulch
Maunalei
1799
1200
2000
sand
mud
shells
coral
rocky
gravel
stones
coral reef
10
20
50
100

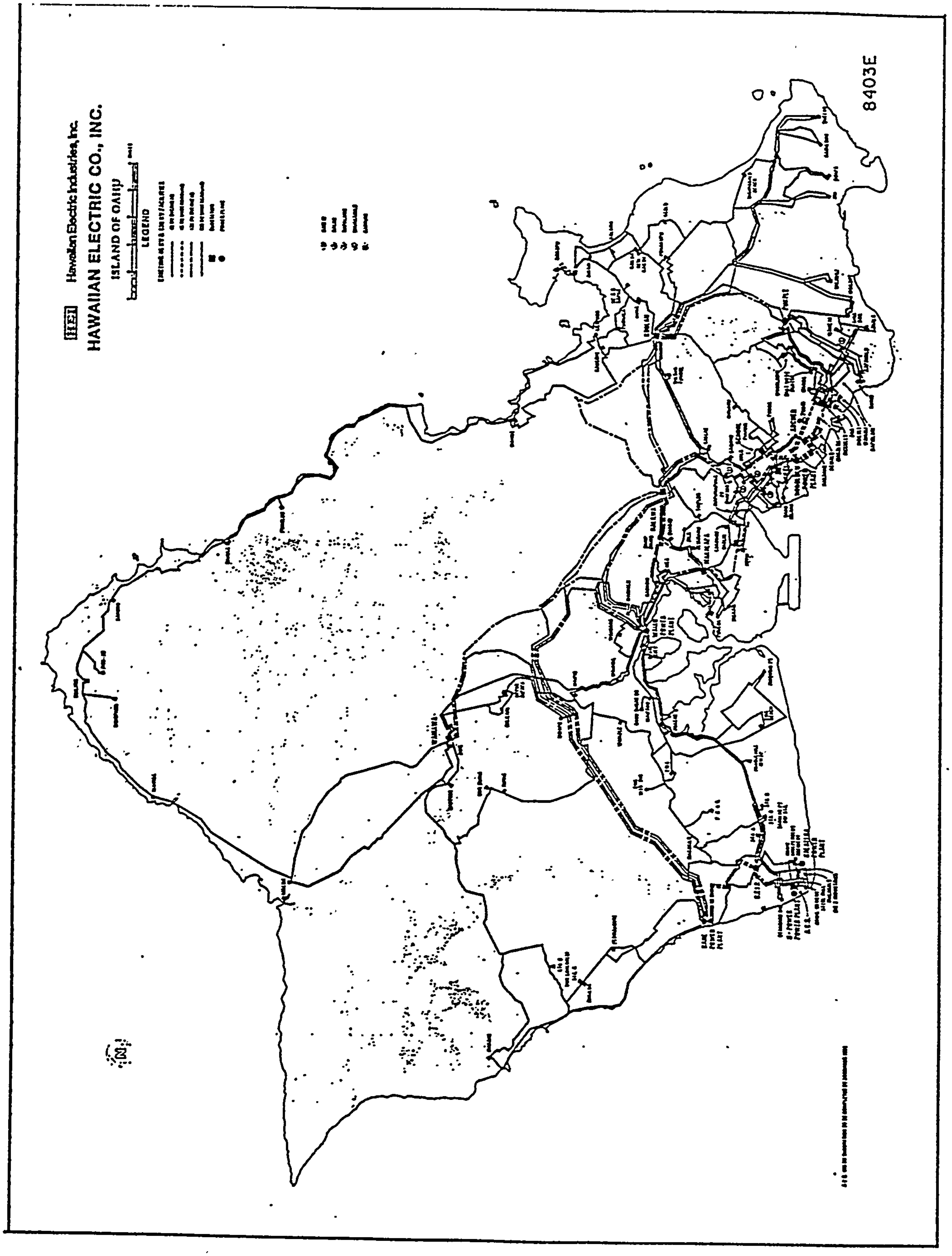

PAILOLO CHANNEL
KALOHI CHANNEL
PALAAU
34KV LINE

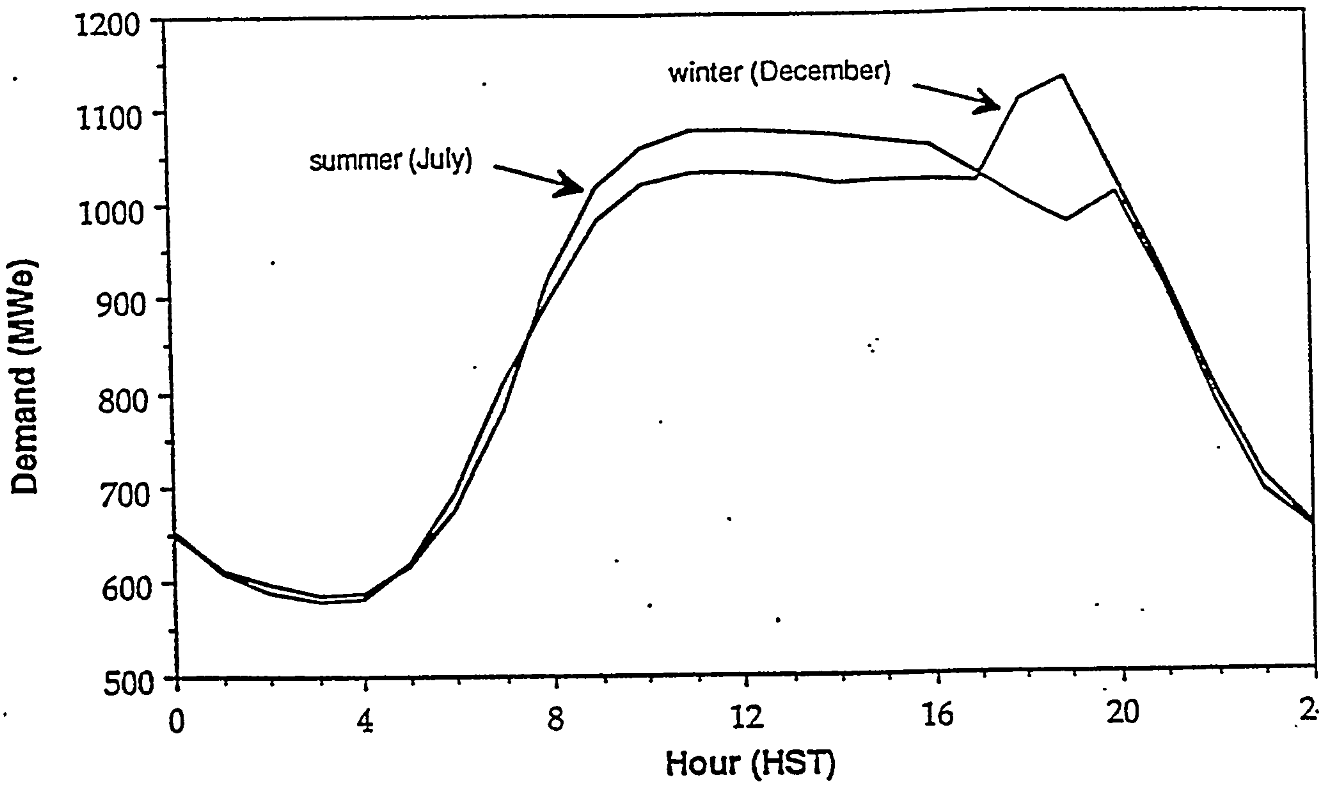


MOECO Typical Daily Load Profiles by Season (based on historical data for 1989)

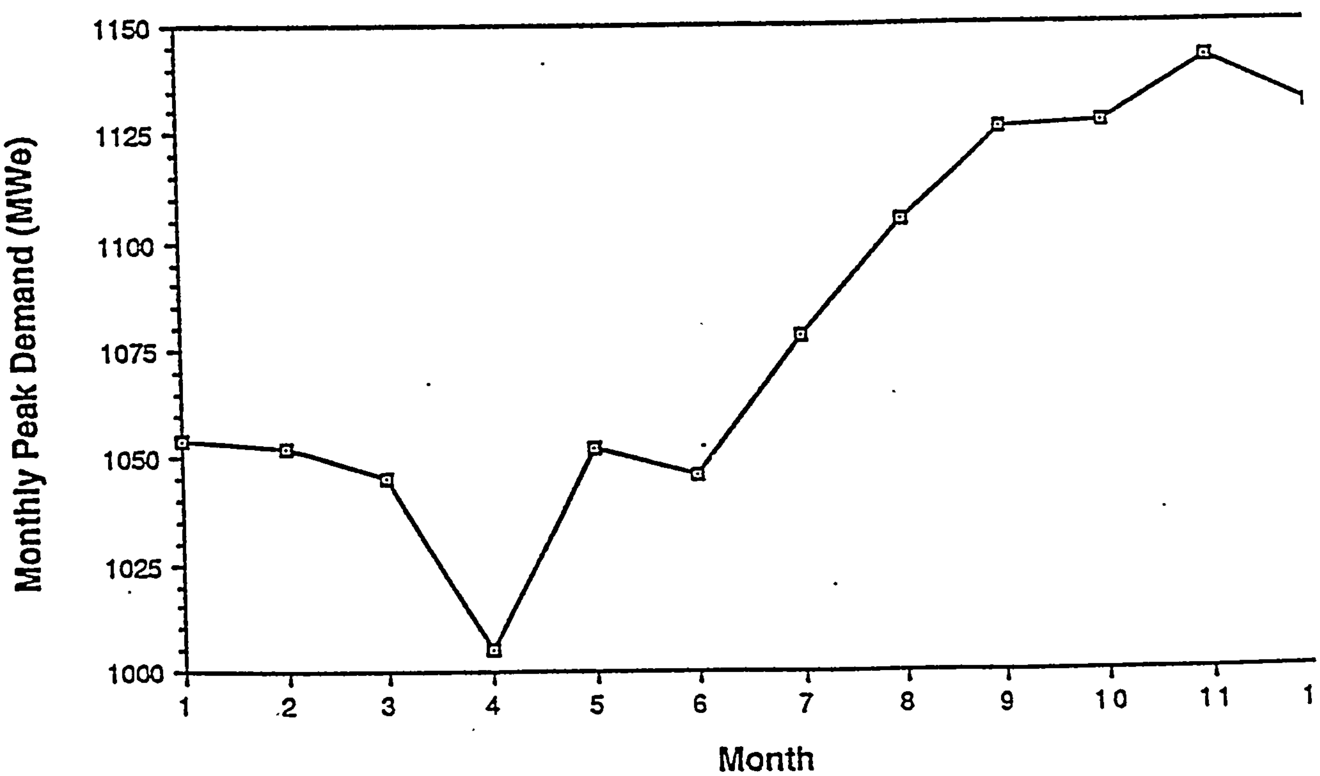


MOECO Peak Demand by Month (based on projected 1991 data)


HEI Hawaiian Electric Industries, Inc.
HAWAIIAN ELECTRIC CO., INC.
ISLAND OF OAHU
LEGEND
8403E



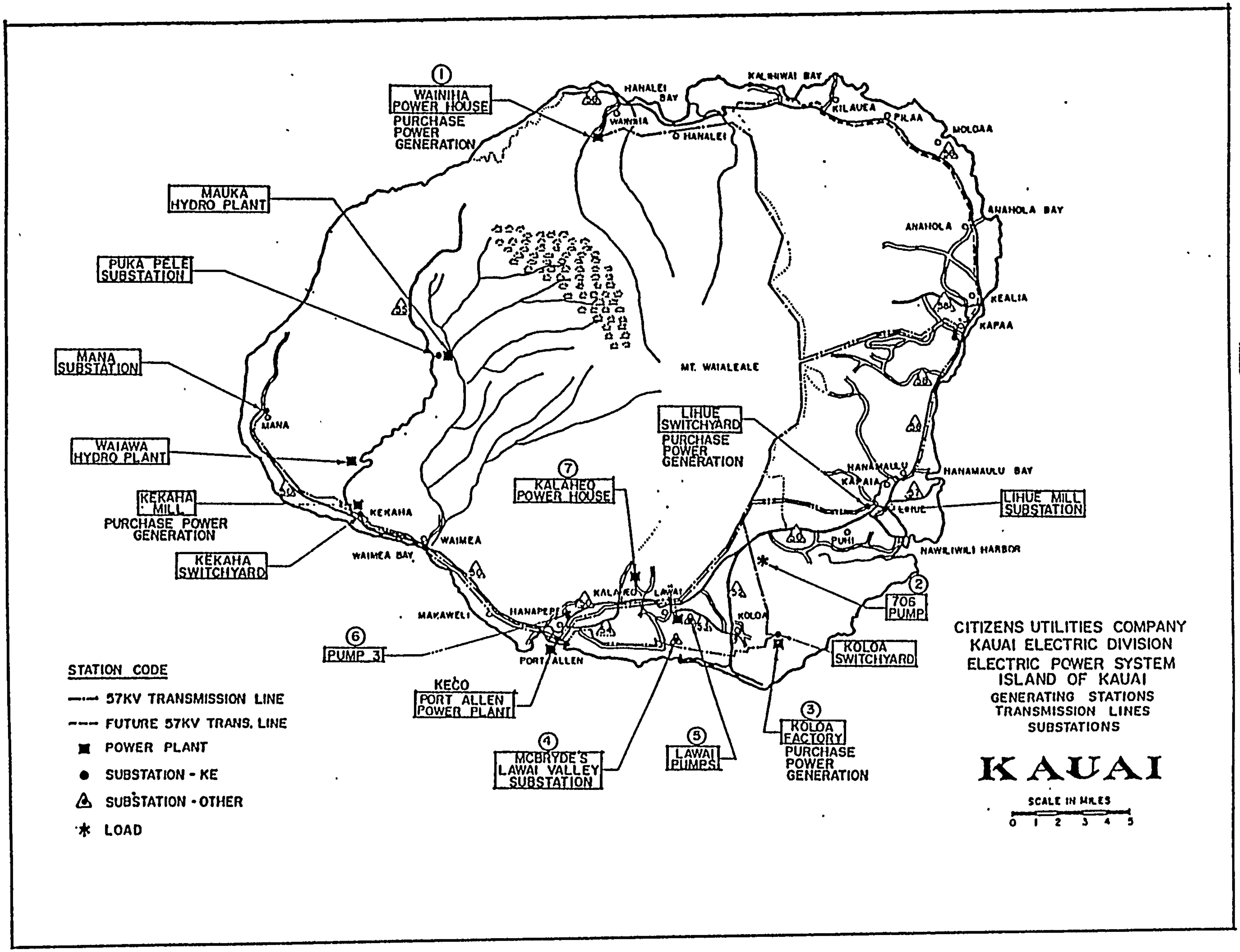
HECO Typical Daily Load Profiles by Season (based on projected 1990 data)



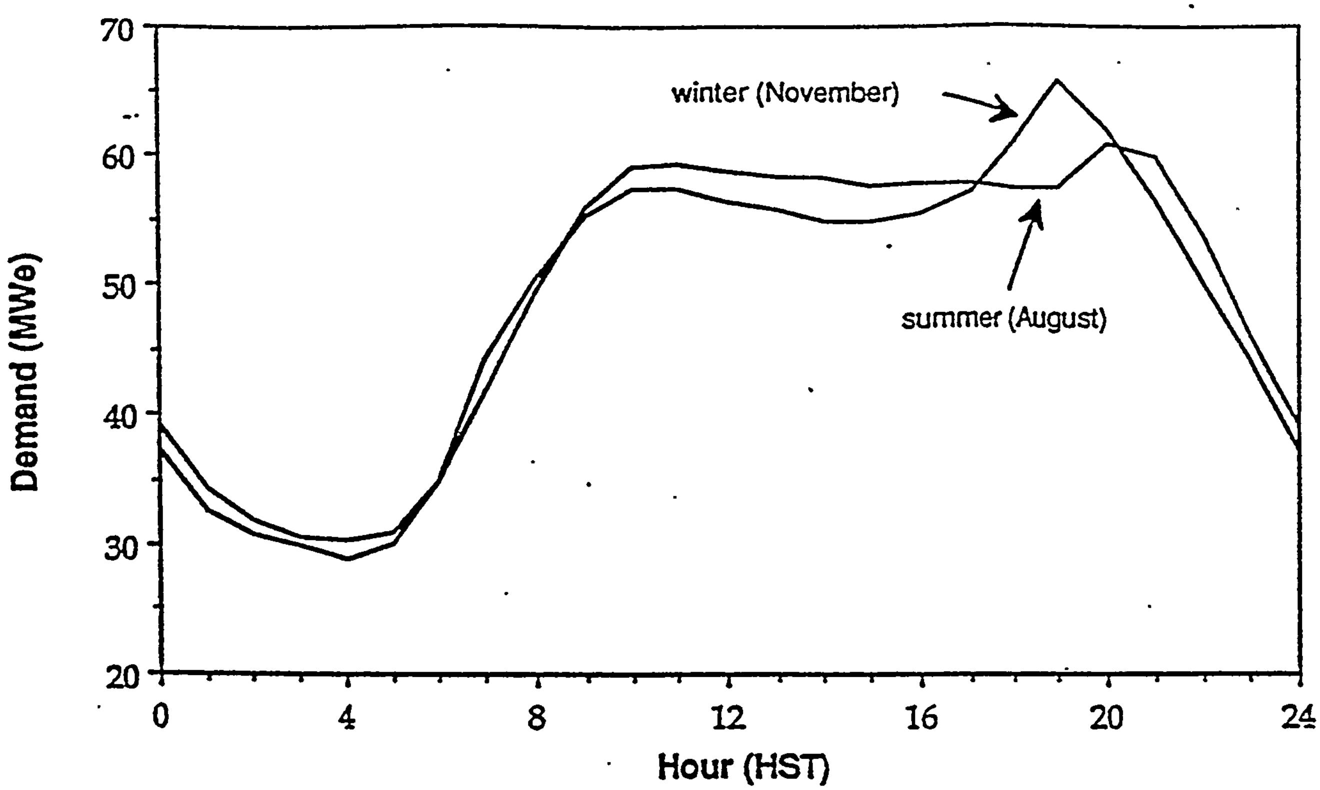
HECO Peak Demand by Month (per Forecast Planning Committee's 1990 peak load forecast, 5/11/90)

Hawaiian Electric Company (HECO) System Resource Plan

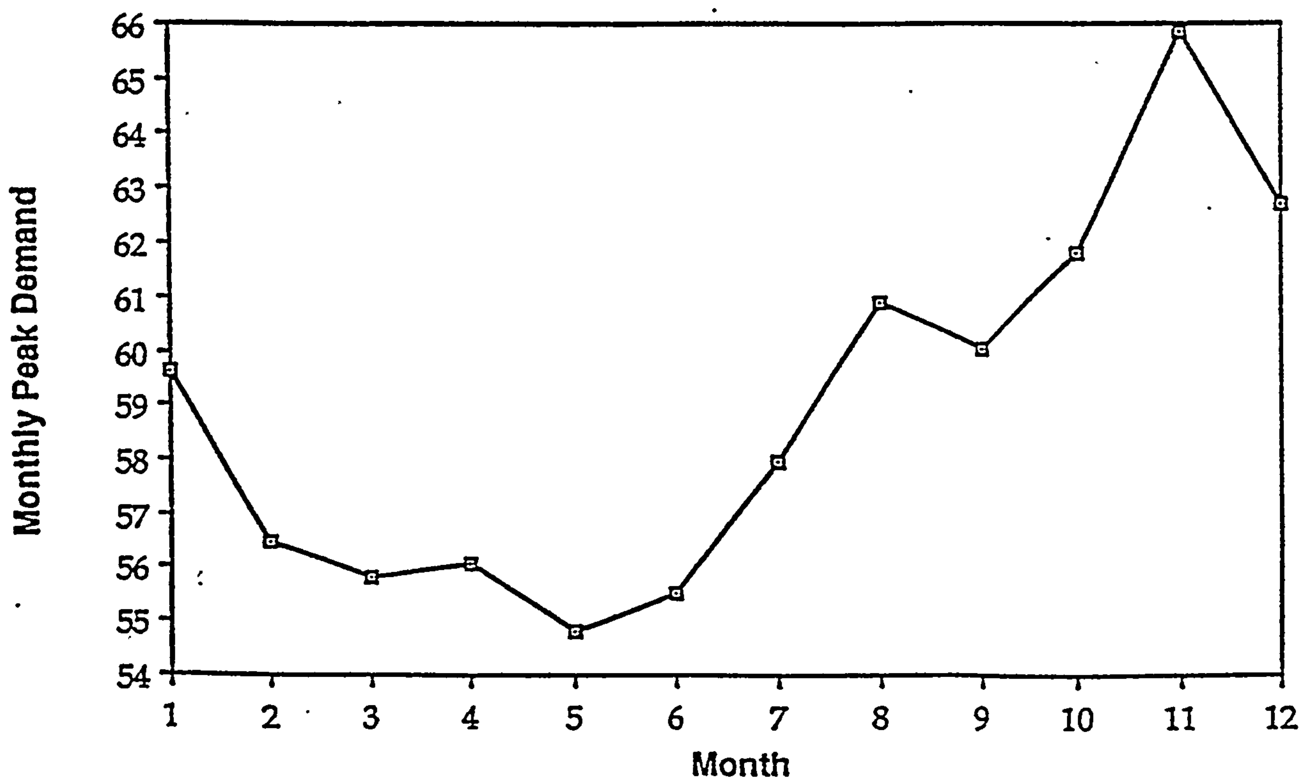
Year	System Peak (MW)	System Capacity (MW)	Reserve Margin (%)	Capacity Modifications Unit	Retired (MW)	Added (MW)
1991	1141	1440	26.2			
1992	1217	1620	33.1	AES	-	180
		1666	36.9	H-POWER	-	46
1993	1254	1666	32.9	-	-	-
1994	1285	1610	25.3	Honolulu 8	56	-
		1553	20.9	Honolulu 9	57	-
1995	1309	1620	23.8	Barbers Point 1, Ph1	-	70
		1620	29.1	Barbers Point 1, Ph2	-	70
1996	1340	1750	30.6	Barbers Point 1, Ph3	-	60
1997	1378	1750	27.0	-	-	-
1998	1406	1827	29.9	Combustion Turbine 1	-	77
1999	1435	1827	27.3	-	-	-
2000	1464	1827	24.8	-	-	-
2001	1488	2027	36.2	Fluidized Bed 1	-	200
2002	1513	2027	34.0	-	-	-
2003	1538	2027	31.8	-	-	-
2004	1563	2027	29.7	-	-	-
2005	1589	2027	27.6	-	-	-
2006	1617	2027	25.4	-	-	-
2007	1646	2227	35.3	Fluidized Bed 2	-	200
2008	1675	2175	29.9	Waiau 9	52	-
		2125	26.9	Waiau 10	50	-
2009	1705	2202	29.1	Combustion Turbine 2	-	77
2010	1736	2153	24.0	Waiau 3	49	-
		2104	21.2	Waiau 4	49	-
2011	1767	2181	23.4	Combustion Turbine 3	-	77



CITIZENS UTILITIES COMPANY
KAUAI ELECTRIC DIVISION
ELECTRIC POWER SYSTEM
ISLAND OF KAUAI
GENERATING STATIONS
TRANSMISSION LINES
SUBSTATIONS
KAUAI
SCALE IN MILES
0 1 2 3 4 5
STATION CODE
57KV TRANSMISSION LINE
FUTURE 57KV TRANS. LINE
POWER PLANT
SUBSTATION - KE
SUBSTATION - OTHER
LOAD
1 WAINIHA POWER HOUSE PURCHASE POWER GENERATION
MAUKA HYDRO PLANT
PUKA PELE SUBSTATION
MANA SUBSTATION
WAIAWA HYDRO PLANT
KEKAHA MILL PURCHASE POWER GENERATION
KEKAHA SWITCHYARD
6 PUMP 3
KECO PORT ALLEN POWER PLANT
4 MCBRYDE'S LAWAI VALLEY SUBSTATION
5 LAWAI PUMPS
3 KOLOA FACTORY PURCHASE POWER GENERATION
KOLOA SWITCHYARD
2 706 PUMP
LIHUE MILL SUBSTATION
LIHUE SWITCHYARD PURCHASE POWER GENERATION
7 KALAHEO POWER HOUSE
HANALEI BAY
WAINIHA
HANALEI
KALIHIWAI BAY
KILAUEA
PILAA
MOLOAA
ANAHOLA BAY
ANAHOLA
KEALIA
KAPAA
MT. WAIALEALE
HANAMAULU
HANAMAULU BAY
KAPAIA
LIHUE
PUHI
NAWILIWILI HARBOR
KOLOA
LAWAI
KALAHEO
HANAPEPE
PORT ALLEN
MAKAWELI
WAIMEA
WAIMEA BAY
KEKAHA
MANA



KE Typical Daily Load Profiles by Season (based on historical data for 1990)



KE Peak Demand by Month (based on historical data for 1990)

Kauai Electric System Resource Plan

Year	System Peak (MW)	System Capacity (MW)	Reserve Margin (%)	Capacity Modifications Unit	Retired (MW)	Added (MW)
1991	69.8	108.3	55.2			
1992	73.7	108.3	46.9	-	-	-
1993	78.7	108.3	37.6	-	-	-
1994	83.6	108.3	30.0	-	-	-
1995	87.6	123.9	41.4	additions*	-	15.6
1996	91.5	123.9	35.4	-	-	-
1997	95.5	123.9	29.7	-	-	-
1998	99.4	123.9	24.6	-	-	-
1999	103.4	139.5	34.9	additions	-	15.6
2000	107.3	139.5	30.0	-	-	-
2001	111.3	139.5	25.3	-	-	-
2002	115.2	139.5	21.1	-	-	-
2003	118.2	155.1	31.2	additions	-	15.6
2004	123.1	155.1	26.0	-	-	-
2005	127.1	155.1	22.0	-	-	-
2006	131.0	155.1	18.4	-	-	-
2007	135.0	170.7	26.4	additions	-	15.6
2008	138.9	170.7	22.9	-	-	-
2009	142.9	170.7	19.5	-	-	-
2010	146.8	170.7	16.3	-	-	-

* system capacity total includes a 12 MW firm power contract with the Lihue Power Plant

APPENDIX D

ENVIRONMENTAL AND CULTURAL RATINGS OF POTENTIAL PROJECT SITES

Table of Environmental/Cultural Conflict Levels for Potential Renewable Energy Sites

Project Identification				Conflict Level	Environmental Concerns	Cultural Concerns
W1	Hawaii	Wind	Lalamilo Wells	2		agricultural terraces
W2	Hawaii	Wind	North Kohala	4		nearby cultural sites
W3	Hawaii	Wind	Kahua Ranch	2	rare native communities	agricultural terraces
W4	Hawaii	Wind	Southpoint	1	anchialine pools	known cultural sites
S1	Hawaii	Solar	Waikoloa	3	anchialine pools & lava caves	many sites makai of highway
S2	Hawaii	Solar	Keahole Point	4		nearby cultural sites
S3	Hawaii	Solar	North Kohala	4		nearby cultural sites
O1	Hawaii	OTEC	Keahole Point	4	coral reef communities	
W1	Maui	Wind	West Maui	3	rare & endangered species	known cultural sites
W2	Maui	Wind	McGregor Point	5		
W3	Maui	Wind	Puunene (old airport)	5		
W4	Maui	Wind	NW slope-Haleakala	5		
S1	Maui	Solar	Puunene (old airport)	5		
S2	Maui	Solar	Kihei	3	rare plants & lava tubes	
S3	Maui	Solar	Kahului Airport	5		
W1	Molokai	Wind	West Molokai	5		
S1	Molokai	Solar	West Molokai	5		burial grounds, adze quarry
W1	Lanai	Wind	Shipwreck Beach	4	rare & endangered species	
S1	Lanai	Solar	Manele Bay	3	native plants	scattered sites
W1	Oahu	Wind	Kahuku Hills	3	endangered waterbirds	
W2	Oahu	Wind	Kahuku Flats	3	endangered waterbirds	known cultural sites
W3	Oahu	Wind	Kaena Point	2	endangered waterbirds	
W4	Oahu	Wind	Kanoehe	n/a	not available	not available
S1	Oahu	Solar	Pearl Harbor	4	endangered waterbirds	early fishponds
S2	Oahu	Solar	Lualualei	n/a	not available	not available
S3	Oahu	Solar	N. Ewa Plain	5		
S4	Oahu	Solar	Ewa Plain	4	endangered plants & anchialine pools	
O1	Oahu	OTEC	Kahe Point	3	coral reef communities	
W1	Kauai	Wind	N. of Hanapepe	4	rare species	
W2	Kauai	Wind	S. of Kilauea/Anahola	3	endangered waterbirds	
W3	Kauai	Wind	Port Allen	1	native species	burial sites
S1	Kauai	Solar	Barking Sands	2	endangered waterbirds	known cultural sites

Conflict Levels:

1	high conflict, resolution highly unlikely
2	high conflict, resolution likely with extensive adjustments
3	medium conflict, resolution likely with minor adjustments
4	minor conflict, resolution likely with no adjustments
5	no forseeable conflict

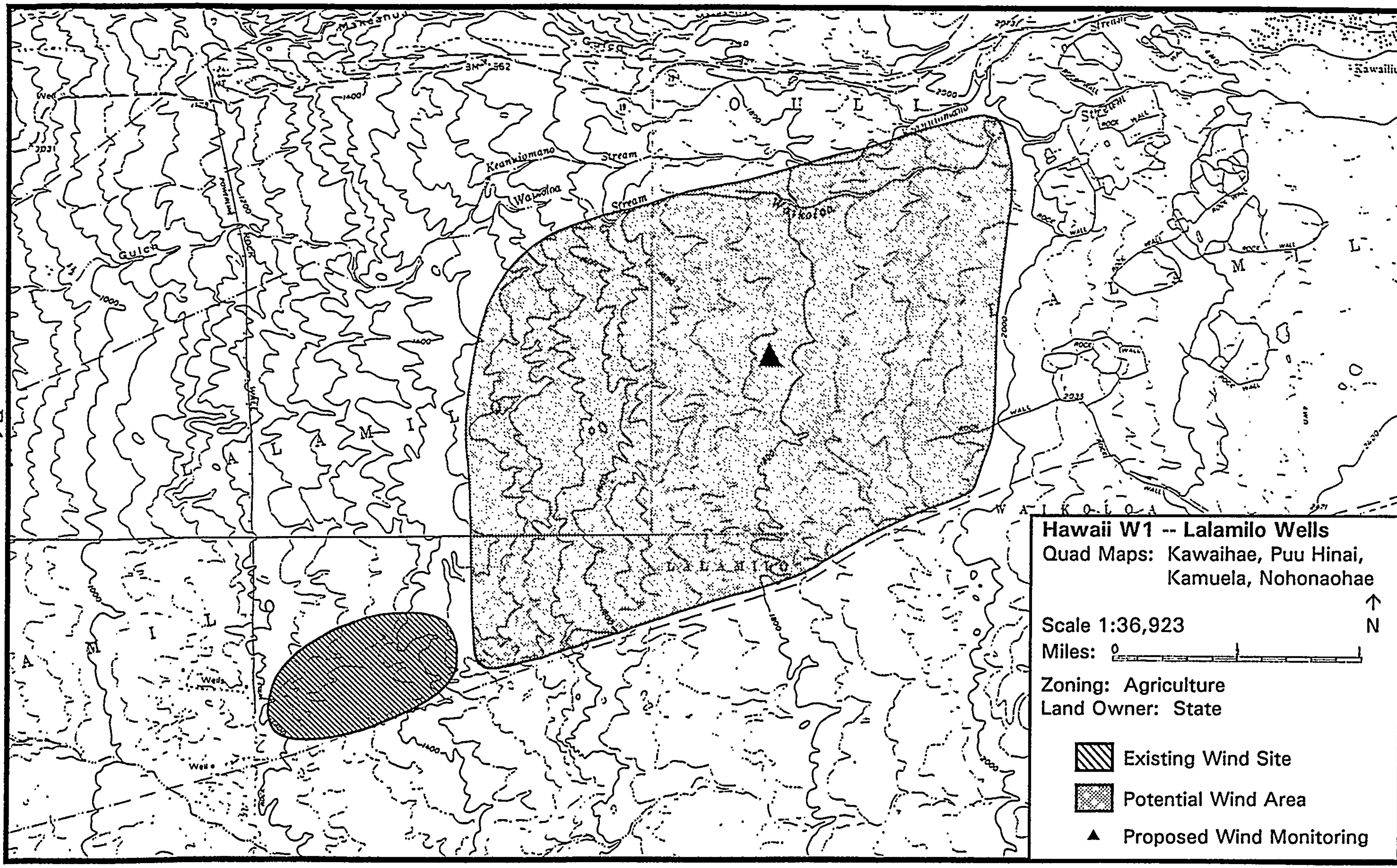
Notes:

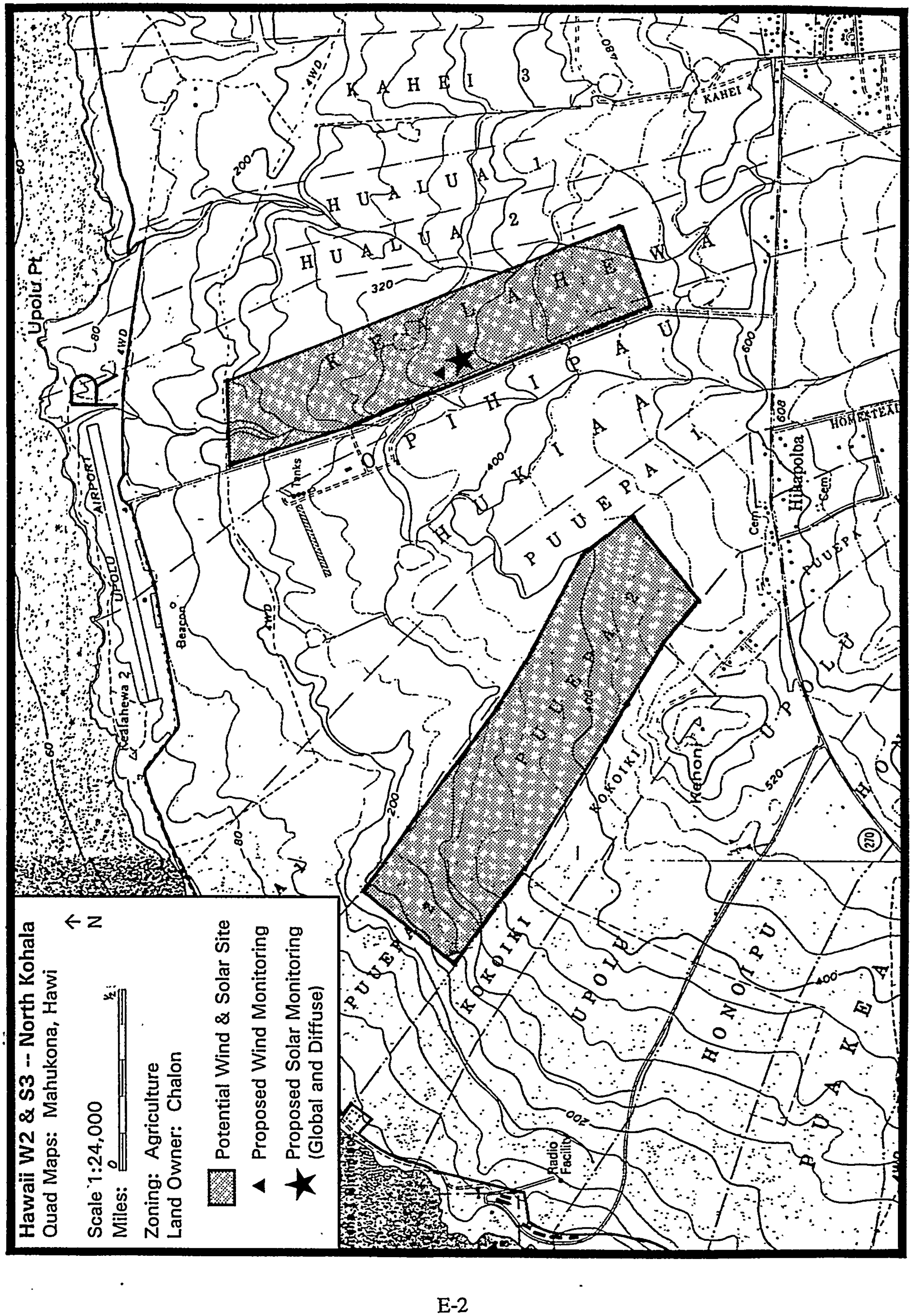
All biomass projects considered acceptable (level 5) because of siting on current agricultural land.
All hydroelectric projects considered to have the highest level of conflict (level 1)
The conflict levels assigned here reflect the opinion of R. Lynette & Associates based on current levels of research and investigation. Further input from Hawaiian communities near the potential project sites would likely alter the currently assessed rating levels.

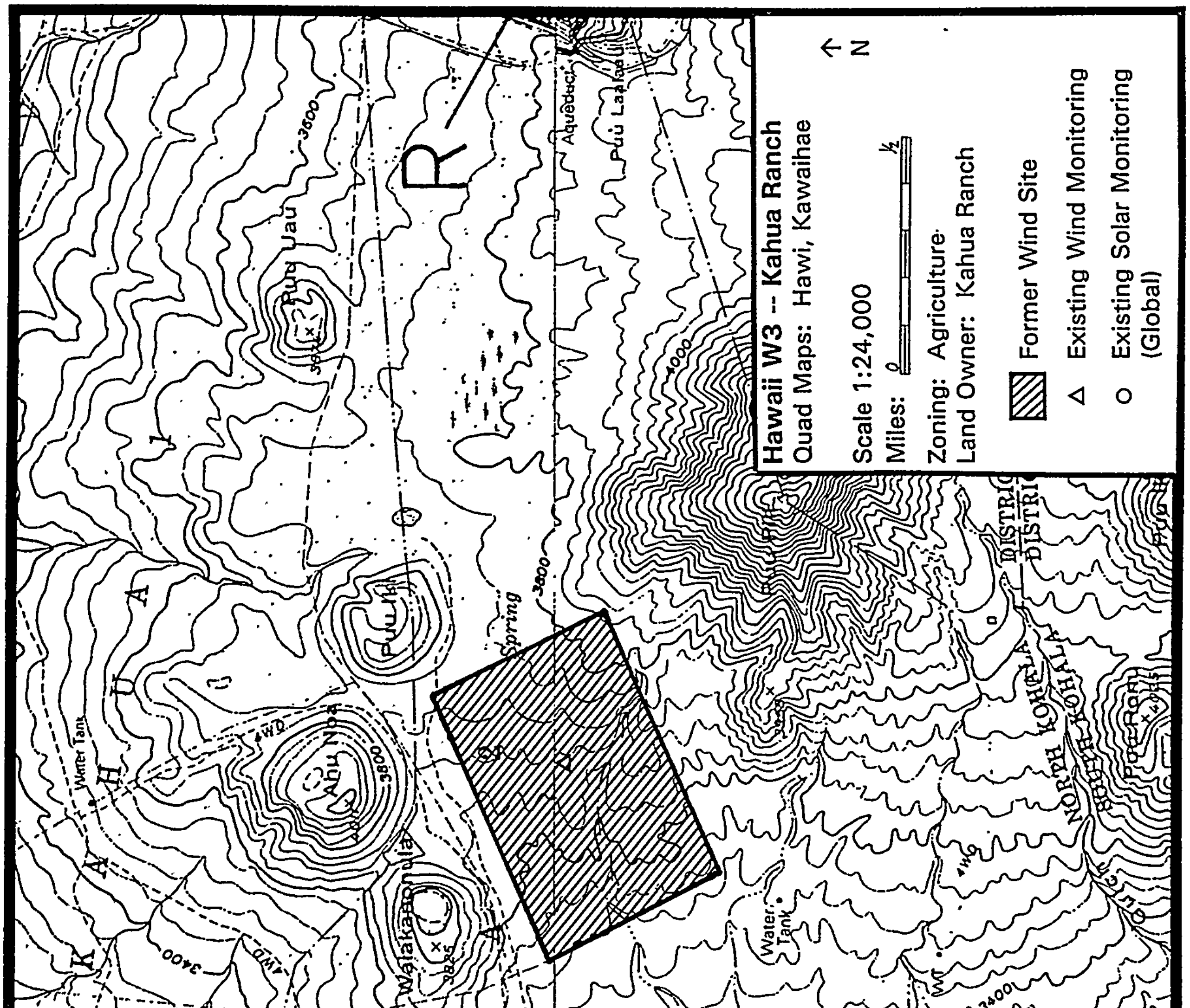
APPENDIX E

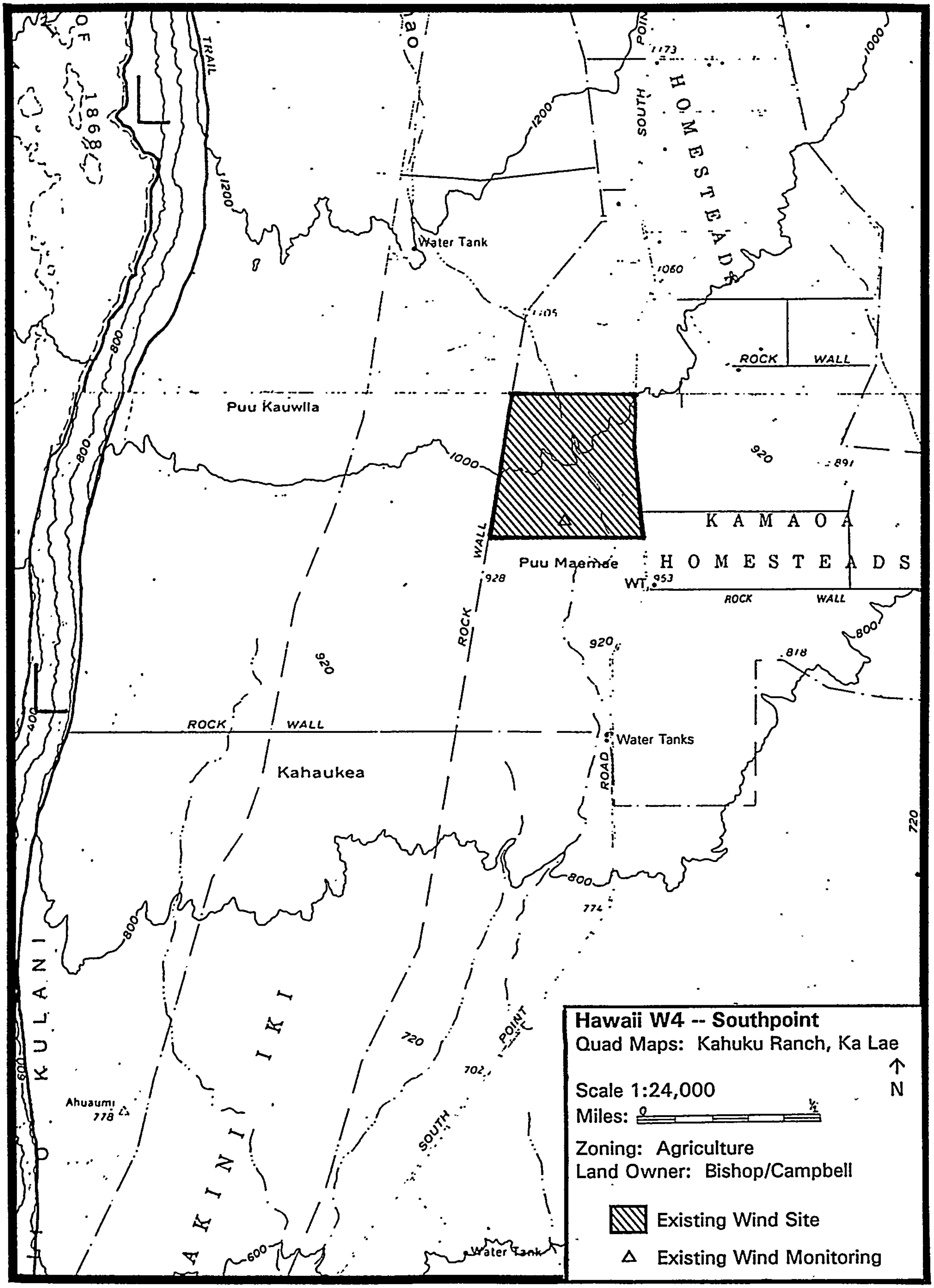
HAWAII SITE MAPS

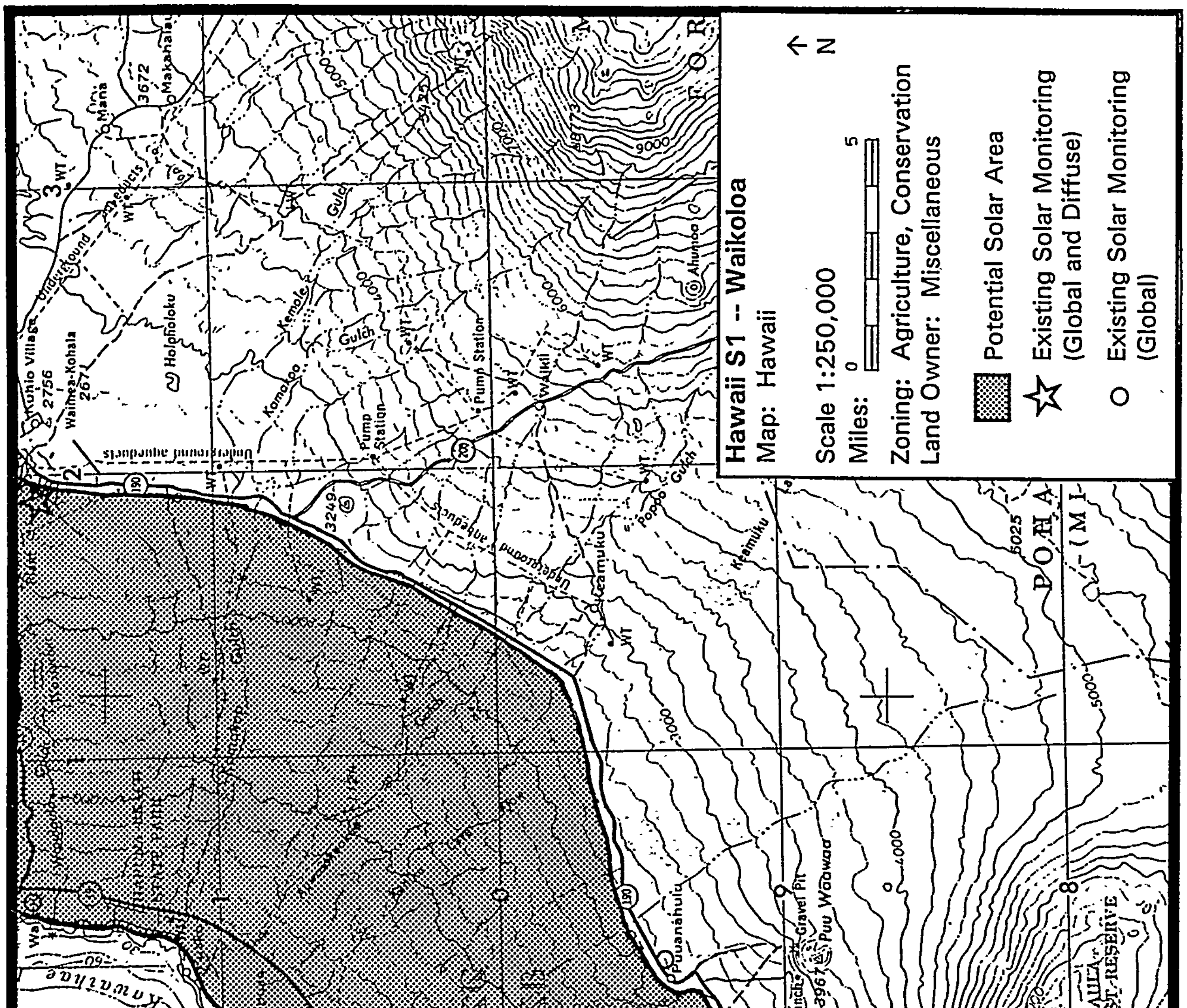
Hawaii W1	Lalamilo Wells
Hawaii W2 & S3	North Kohala
Hawaii W3	Kahua Ranch
Hawaii W4	South Point
Hawaii S1	Waikoloa
Hawaii O1 & S2	Keahole Point

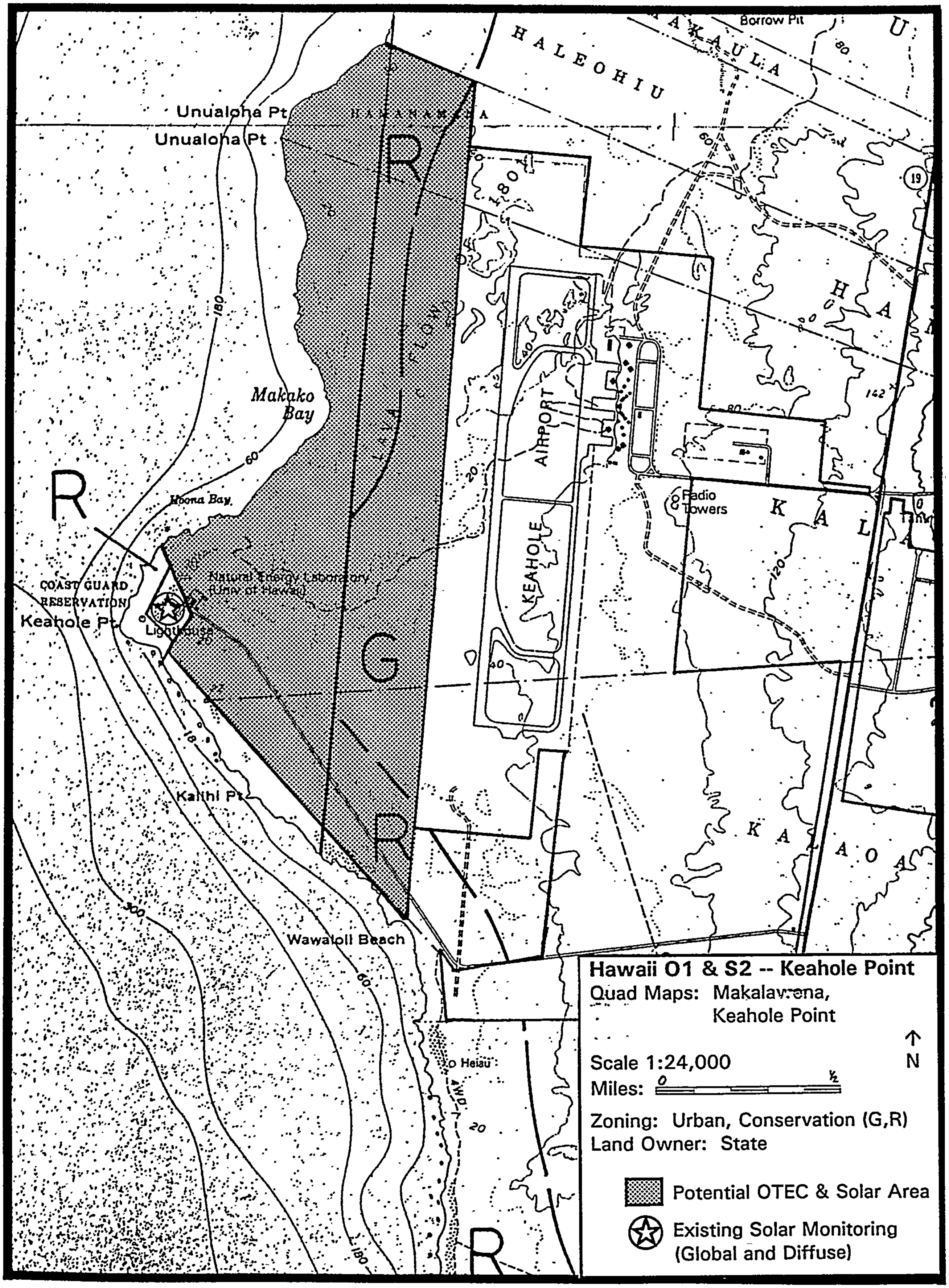

Hawaii W1 -- Lalamilo Wells
Quad Maps: Kawaihae, Puu Hinai, Kamuela, Nohonaohae
N
Scale 1:36,923
Miles: 0
Zoning: Agriculture
Land Owner: State
Existing Wind Site
Potential Wind Area
Proposed Wind Monitoring
Keanuiomano
Stream
Waikoloa
Gulch
Wells
Kawaihae


Hawaii W2 & S3 -- North Kohala
Quad Maps: Mahukona, Hawi
Scale 1:24,000
Miles: 0 ½
N
Zoning: Agriculture
Land Owner: Chalon
Potential Wind & Solar Site
Proposed Wind Monitoring
Proposed Solar Monitoring (Global and Diffuse)
Upolu Pt
UPOLU AIRPORT
Beacon
Kealahewa 2
KAHEI 3
HUALUA 1
HUALUA 2
KEALAHEWA
OPIHIPAU
HUKIAA
PUUEPA 1
PUUEPA 2
KOKOIKI
UPOLU
HONOIPU
PUAKEA
Hikapoloa
HOMESTEAD
Kehoni
Radio Facility
Tanks
Cem
270


Hawaii W3 -- Kahua Ranch
Quad Maps: Hawi, Kawaihae
Scale 1:24,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Kahua Ranch
Former Wind Site
Existing Wind Monitoring
Existing Solar Monitoring (Global)
N
Kahua Ranch
Windmill
Water Tank
Corral
Rock Walls
Spring
Aqueduct
NORTH KOHALA
SOUTH KOHALA
Puu Lepo
Puu Laalaau
Puu Uau
Ahu Noa
Waiakaamoamoa


Hawaii W4 -- Southpoint
Quad Maps: Kahuku Ranch, Ka Lae
N
Scale 1:24,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Bishop/Campbell
Existing Wind Site
Existing Wind Monitoring
Water Tank
Puu Kauwila
Puu Maemae
KAMAOA HOMESTEADS
HOMESTEADS
ROCK WALL
SOUTH POINT ROAD
Water Tanks
Kahaukea
KULANI
KAKINIKI
TRAIL
OF 1868
Ahuaumi
778
1200
1000
920
800
720
600
400
1173
1060
1105
891
928
953
818
774
702

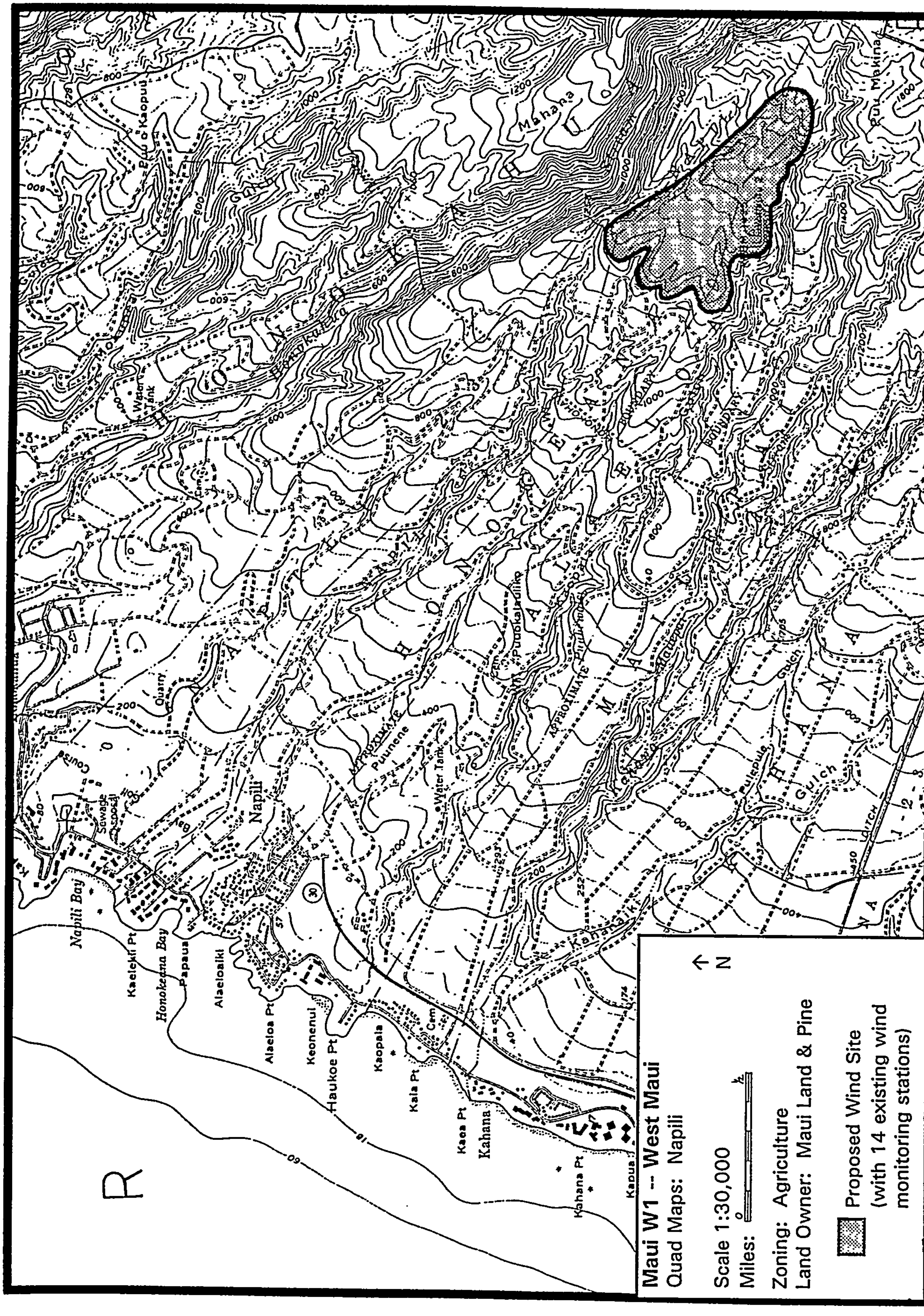

Hawaii S1 -- Waikoloa
Map: Hawaii
Scale 1:250,000
Miles: 0 5
Zoning: Agriculture, Conservation
Land Owner: Miscellaneous
Potential Solar Area
Existing Solar Monitoring (Global and Diffuse)
Existing Solar Monitoring (Global)
N
Kawaihae
Anaehoomalu Bay
Kapalaoa
Keawaiki
Kiholo Bay
Makalawena
Mahaiula
Honokohau Bay
Kalaoa
Palani Junction
Radio Station
Puu Waawaa
Gravel Pit
Puuanahulu
Waimea-Kohala
Kuhio Village
Holoholoku
Pump Station
Waikii
Poopoo Gulch
Kemole Gulch
Ahumoa
Mana
Makahalau
HONUAULA FOREST RESERVE
Hualalai

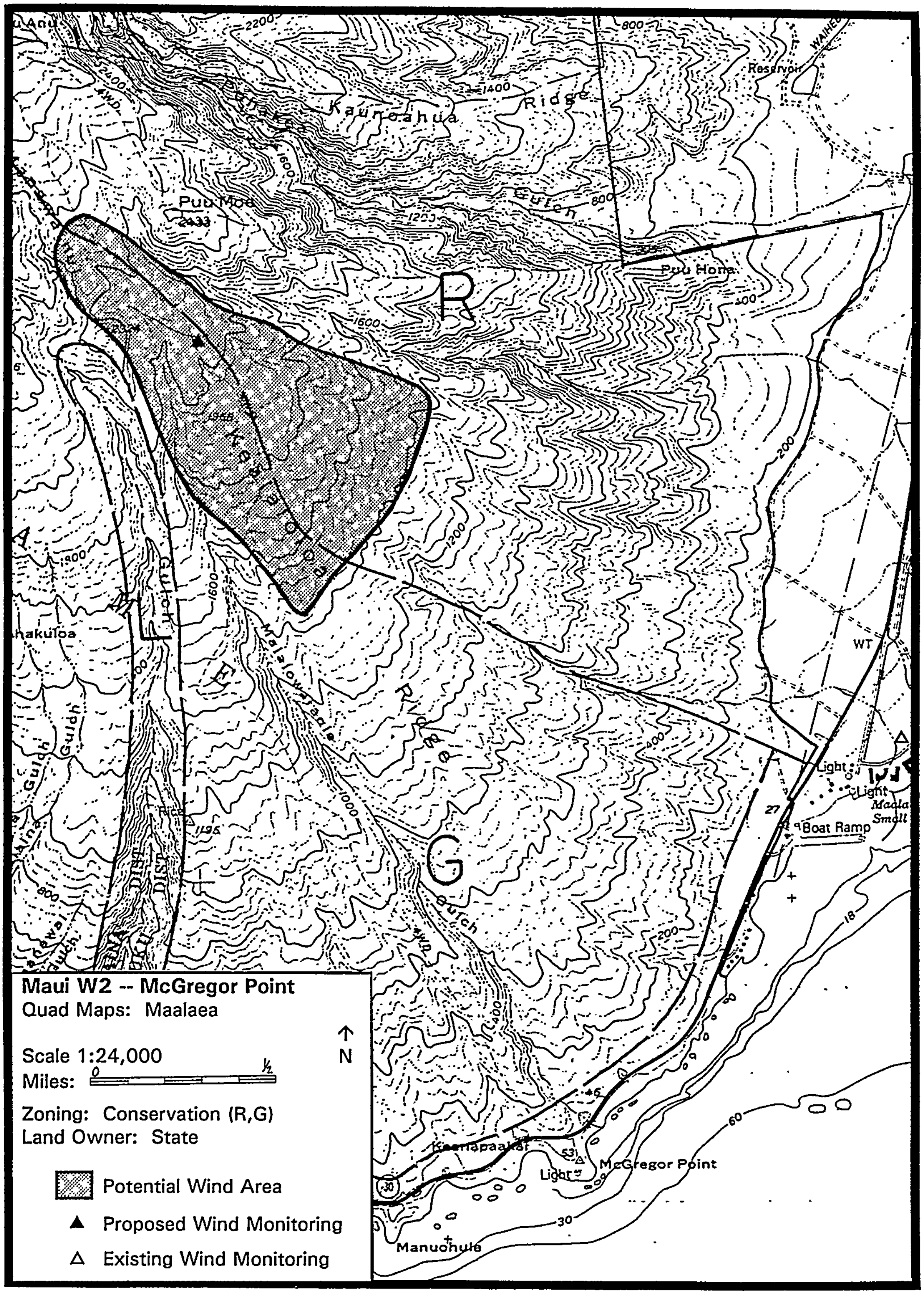

Hawaii O1 & S2 -- Keahole Point
Quad Maps: Makalawena,
Keahole Point
N
Scale 1:24,000
Miles: 0 ½
Zoning: Urban, Conservation (G,R)
Land Owner: State
Potential OTEC & Solar Area
Existing Solar Monitoring
(Global and Diffuse)
Unualoha Pt
Makako Bay
Hoona Bay
COAST GUARD RESERVATION
Keahole Pt
Lighthouse
Natural Energy Laboratory
KEAHOLE AIRPORT
Radio Towers
Kalihi Pt
Wawaloli Beach
Heiau
HALEOHIU
KAKAULA
Borrow Pit
LAVA FLOW
R
G
R
R
R

APPENDIX F

MAUI SITE MAPS

Maui W1	West Maui
Maui W2	McGregor Point
Maui W3	NW Slope of Haleakala
Maui W4 & S1	Puunene
Maui S2	Kihei
Maui S3	Kahului Airport


Maui W1 -- West Maui
Quad Maps: Napili
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Maui Land & Pine
Proposed Wind Site
(with 14 existing wind
monitoring stations)
N
Napili Bay
Kaelekii Pt
Honokeana Bay
Papaua
Alaeloaiki
Alaeloa Pt
Keonenui
Haukoe Pt
Kaopala
Kala Pt
Kaea Pt
Kahana
Kahana Pt
Napili
Quarry
Puunene
Water Tank
Mahana
Kahanaiki



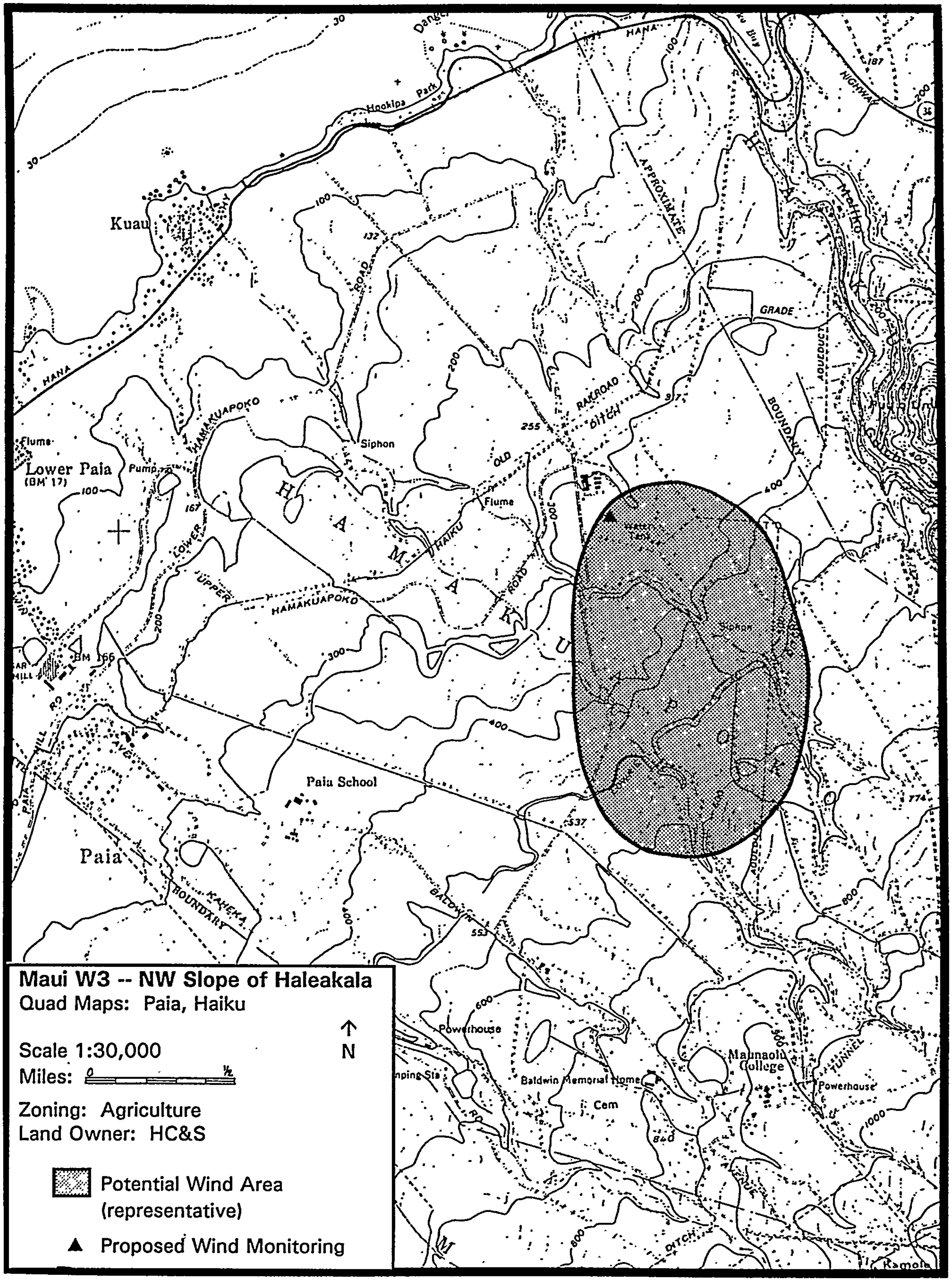
Maui W2 -- McGregor Point
Quad Maps: Maalaea

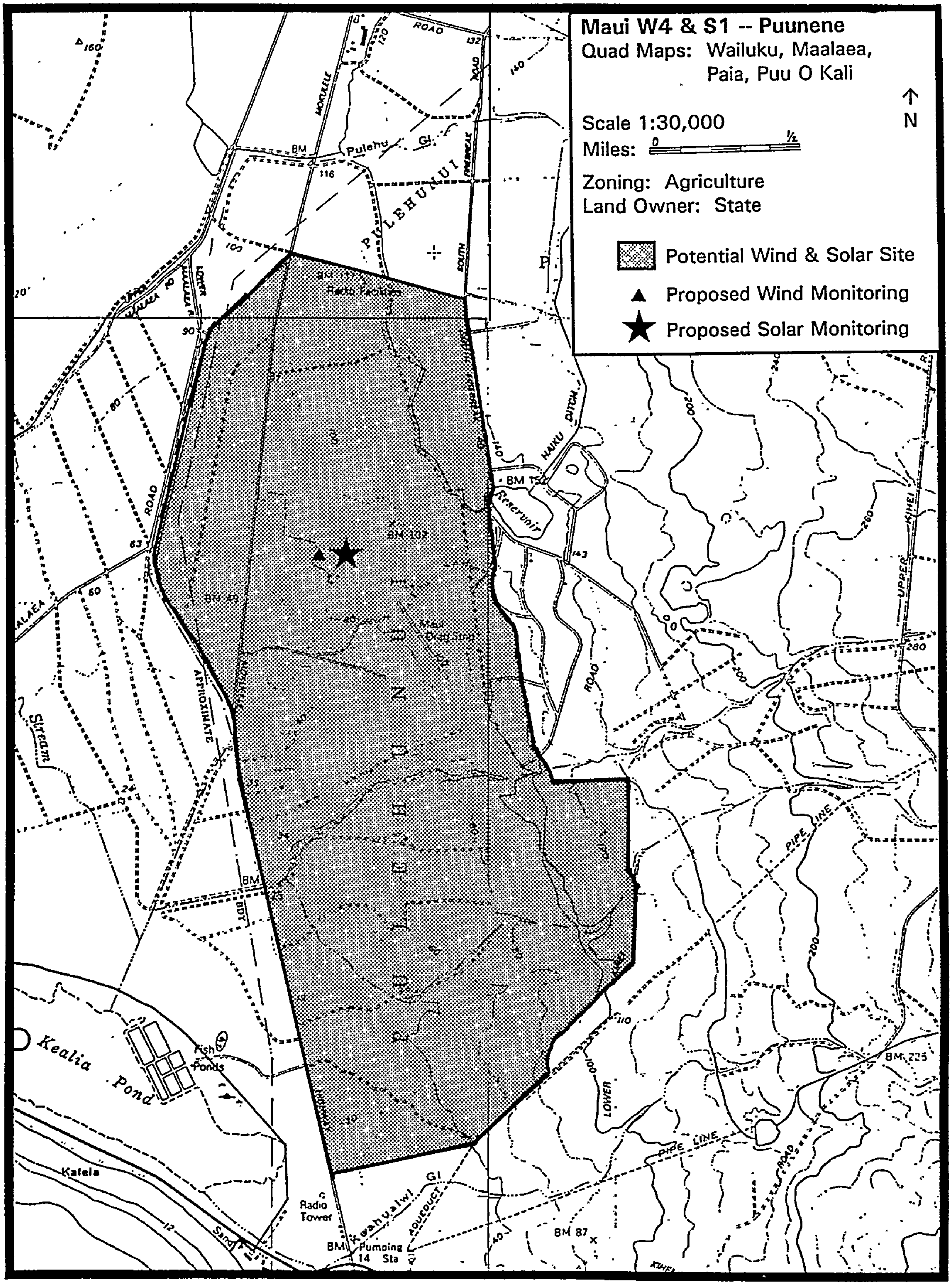
Scale 1:24,000
Miles: 0 ½

N

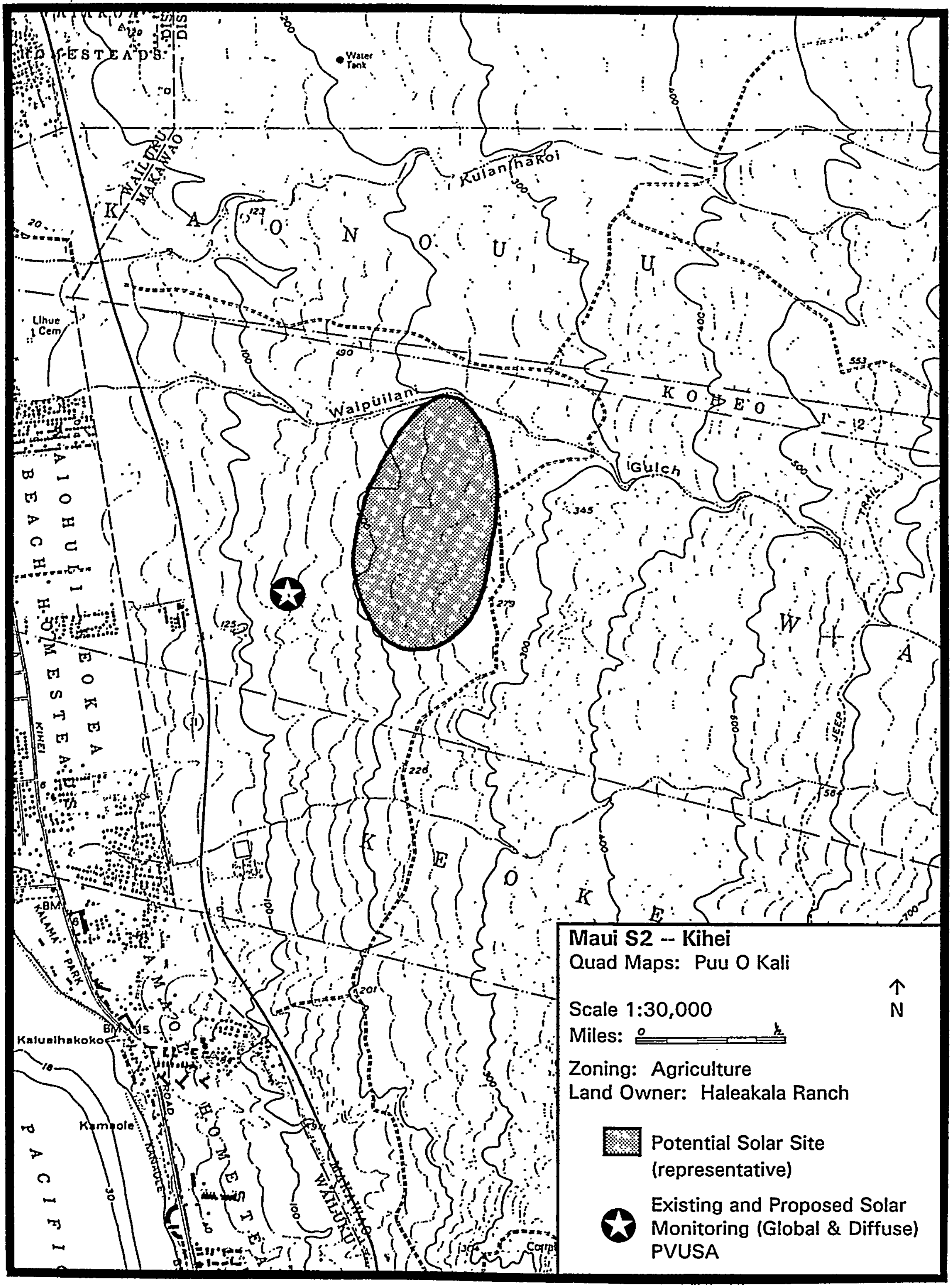
Zoning: Conservation (R,G)
Land Owner: State

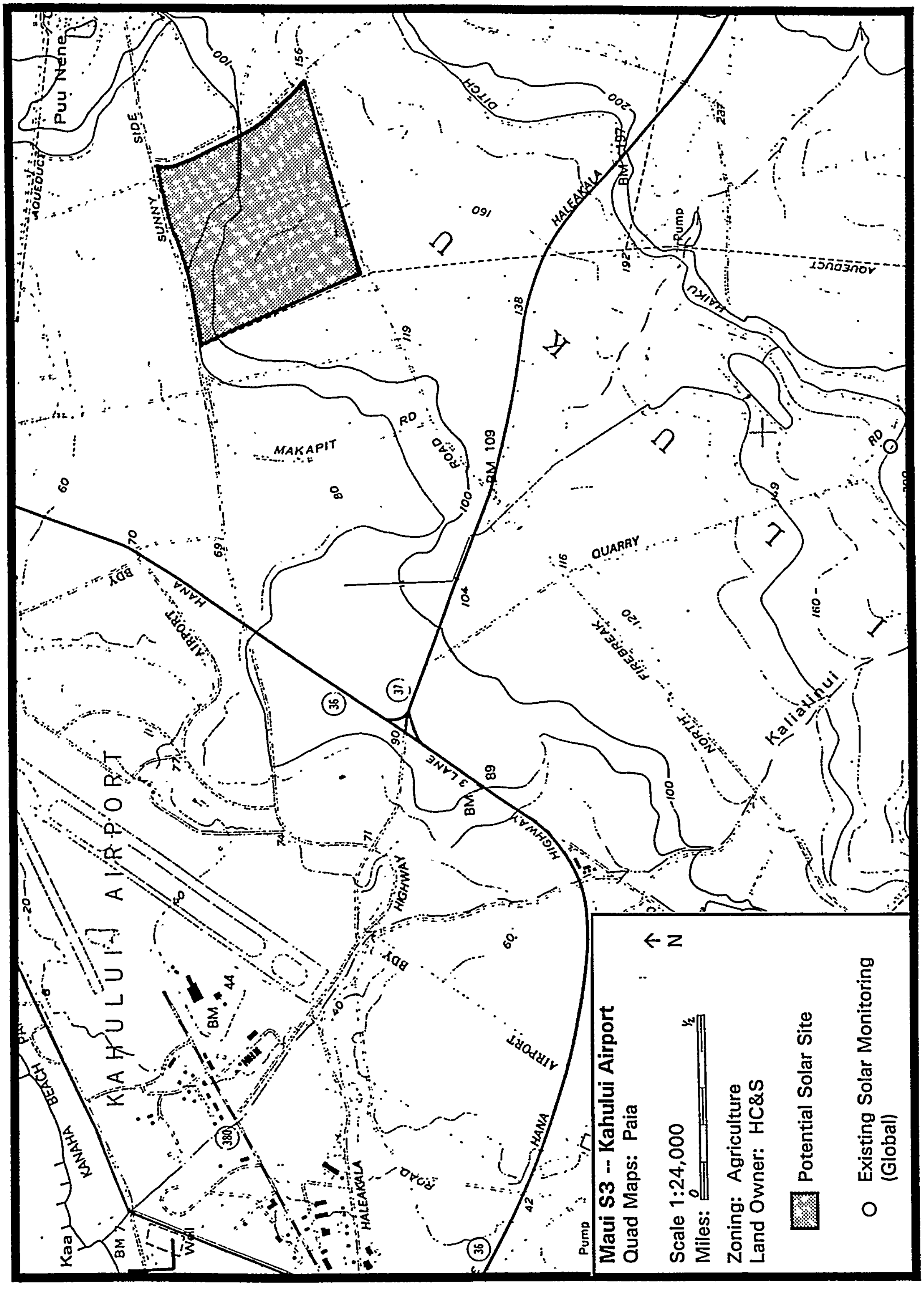
Potential Wind Area
▲ Proposed Wind Monitoring
△ Existing Wind Monitoring


Maui W3 -- NW Slope of Haleakala
Quad Maps: Paia, Haiku
Scale 1:30,000
N
Miles:
Zoning: Agriculture
Land Owner: HC&S
Potential Wind Area (representative)
Proposed Wind Monitoring
Kuau
Lower Paia
Paia
Paia School
Hookipa Park
Siphon
Flume
Powerhouse
Baldwin Memorial Home
Maunaolu College
Cem
HAMAKUAPOKO
APPROXIMATE BOUNDARY
HANA HIGHWAY



Maui W4 & S1 -- Puunene
Quad Maps: Wailuku, Maalaea, Paia, Puu O Kali
Scale 1:30,000
Miles: 0 ½
N
Zoning: Agriculture
Land Owner: State
Potential Wind & Solar Site
Proposed Wind Monitoring
Proposed Solar Monitoring
Kealia Pond
Fish Ponds
Radio Tower
Pumping Sta
Reservoir
HAIKU DITCH
PIPE LINE
PULEHUNUI
APPROXIMATE
ROAD
Stream
Kalela

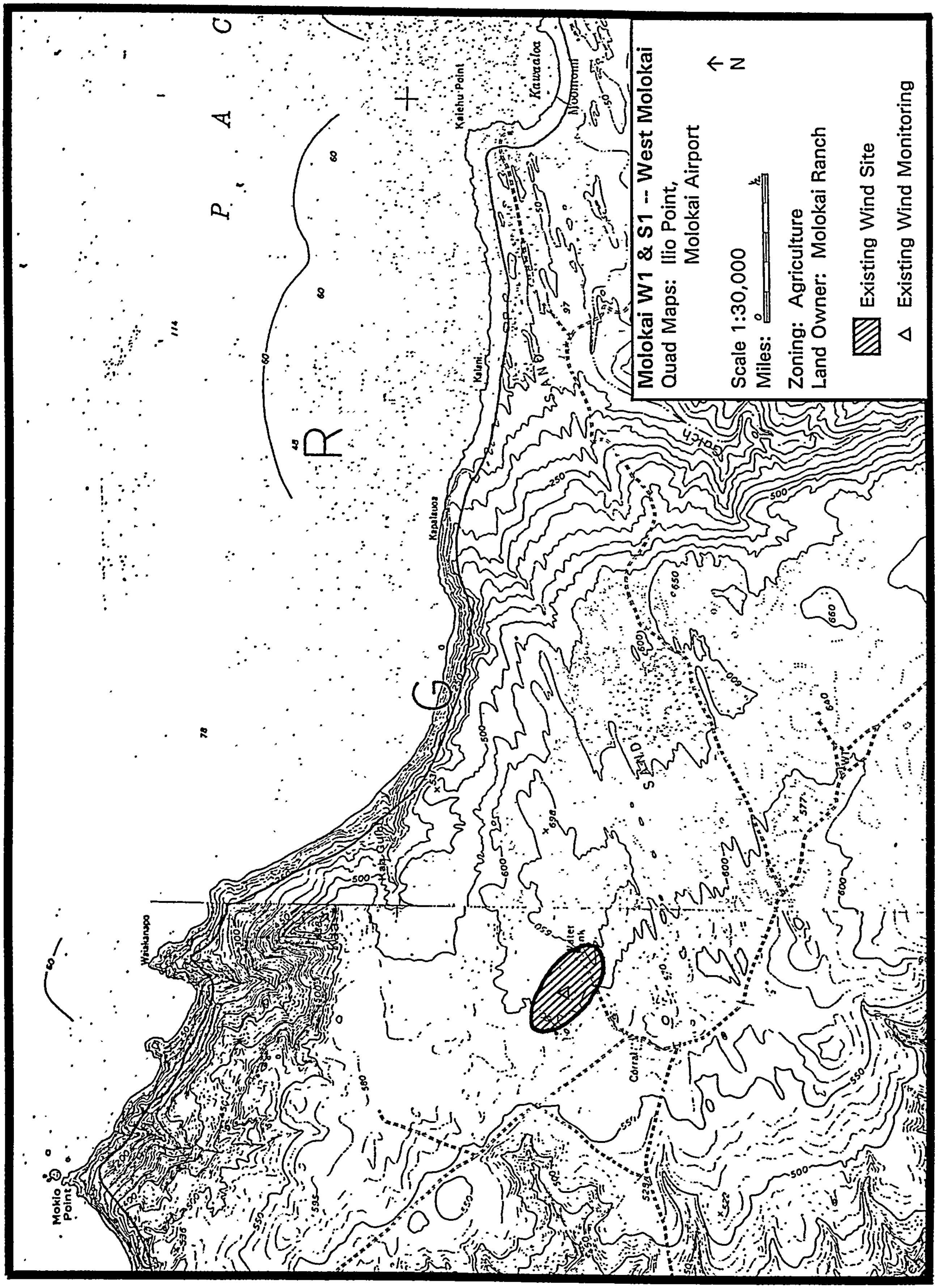

Maui S2 -- Kihei
Quad Maps: Puu O Kali
Scale 1:30,000
Miles: 0 ½
N
Zoning: Agriculture
Land Owner: Haleakala Ranch
Potential Solar Site (representative)
Existing and Proposed Solar Monitoring (Global & Diffuse) PVUSA
Waipuilani
Gulch
Kulanihakoi
KOHEO
Kalualhakoko
Kamaole
Water Tank
Lihue Cem
PACIFIC


Maui S3 -- Kahului Airport
Quad Maps: Paia
Scale 1:24,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: HC&S
Potential Solar Site
Existing Solar Monitoring (Global)
N
KAHULUI AIRPORT
Puu Nene
SUNNY SIDE
AQUEDUCT
MAKAPIT RD
ROAD
HALEAKALA
HAIKU
QUARRY
NORTH FIREBREAK
Kalialinui
HANA HIGHWAY
3 LANE
AIRPORT
KANAHA BEACH
Kaa
Pump
Well

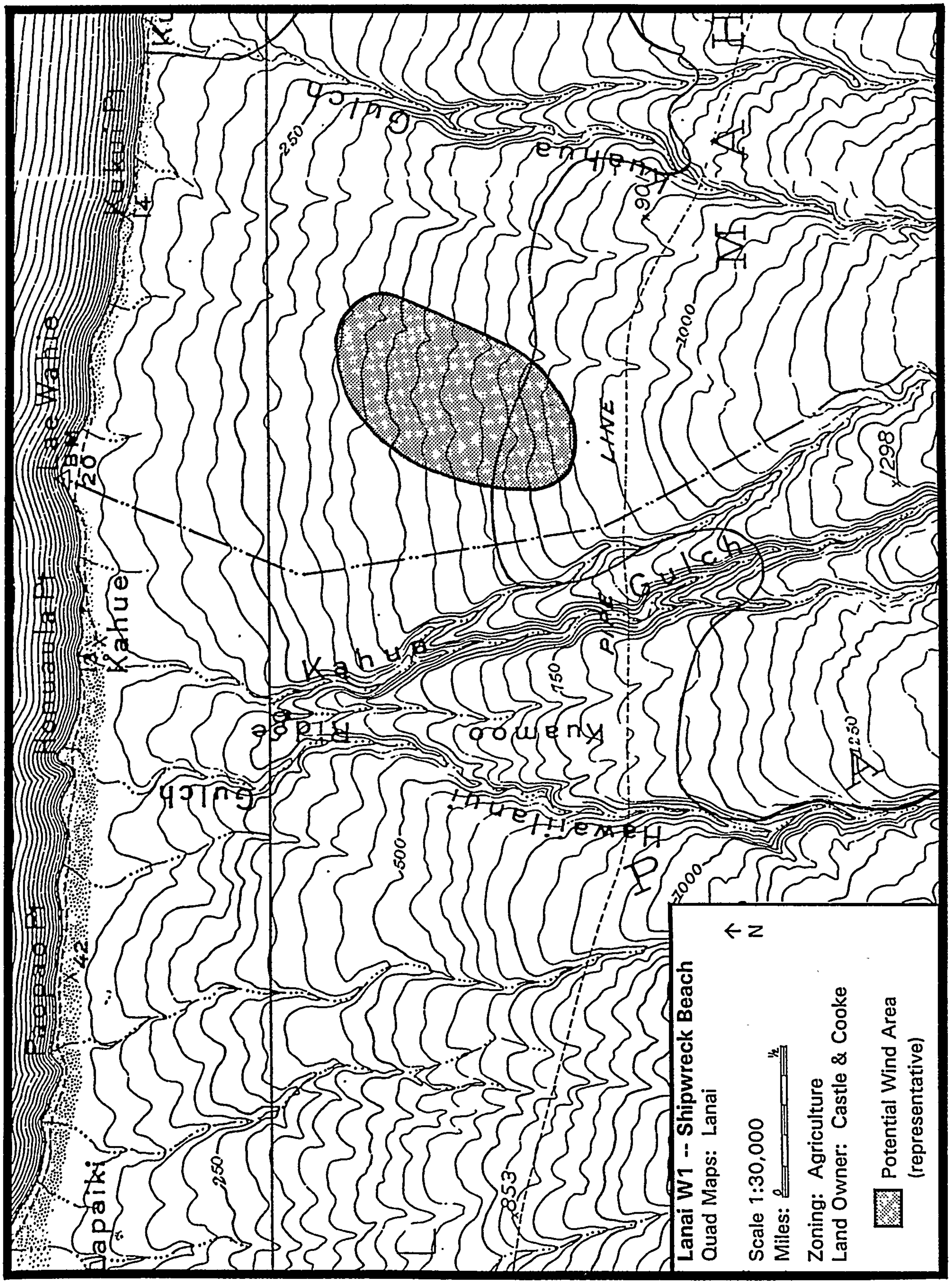
APPENDIX G

MOLOKAI AND LANAI SITE MAPS

Molokai W1 & S1	West Molokai
Lanai W1	Shipwreck Beach



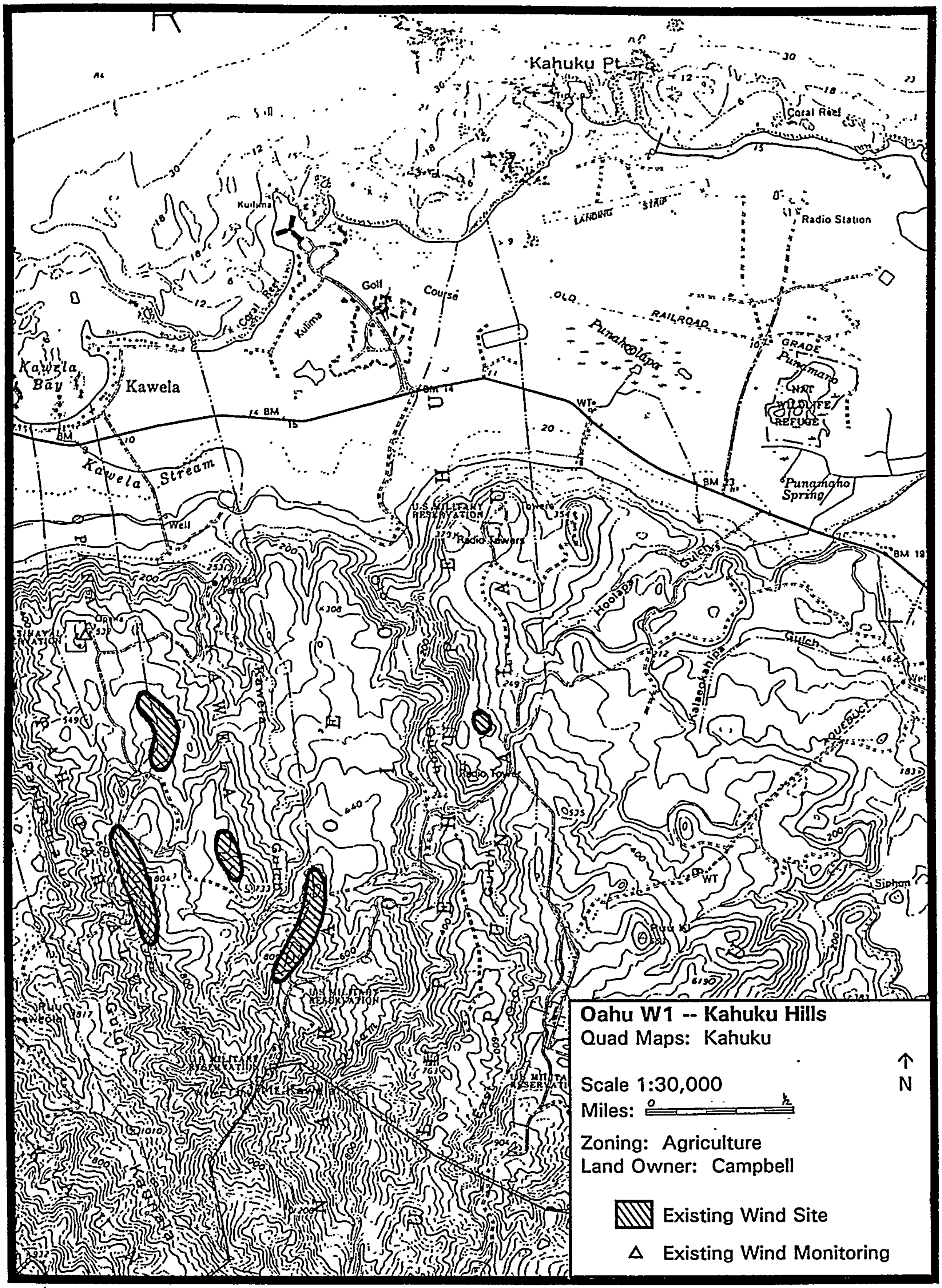
Molokai W1 & S1 -- West Molokai
Quad Maps: Ilio Point,
Molokai Airport
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Molokai Ranch
Existing Wind Site
Existing Wind Monitoring
N
P A C
R
G
Mokio Point
Waiakanapo
Kapalauoa
Kalani
Kaleihu Point
Kawaaloa
Corral
SAND


Lanai W1 -- Shipwreck Beach
Quad Maps: Lanai
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Castle & Cooke
Potential Wind Area (representative)
N
Kahue
Kahua
Gulch
LINE
2000
1000
500
750
250

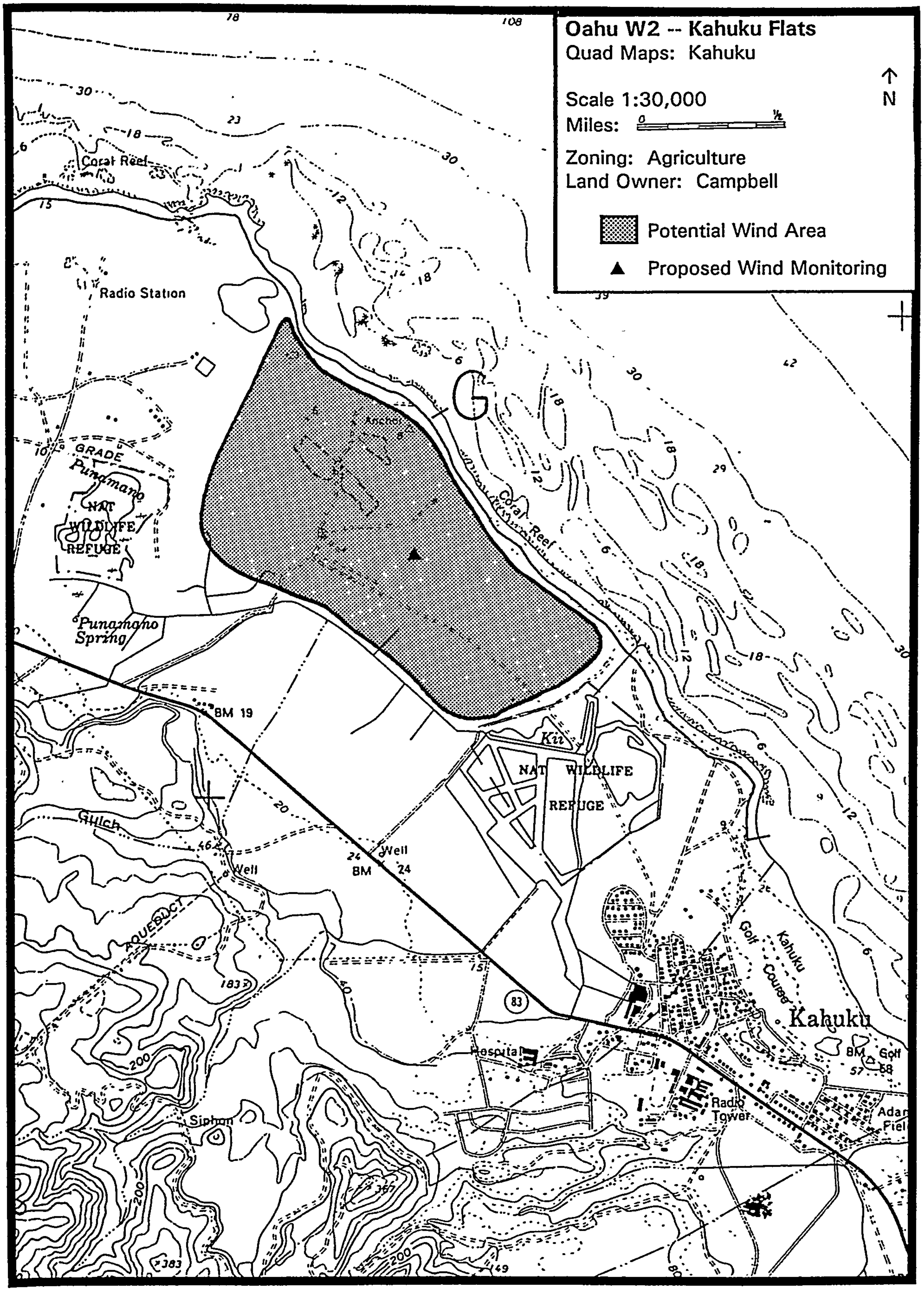
APPENDIX H

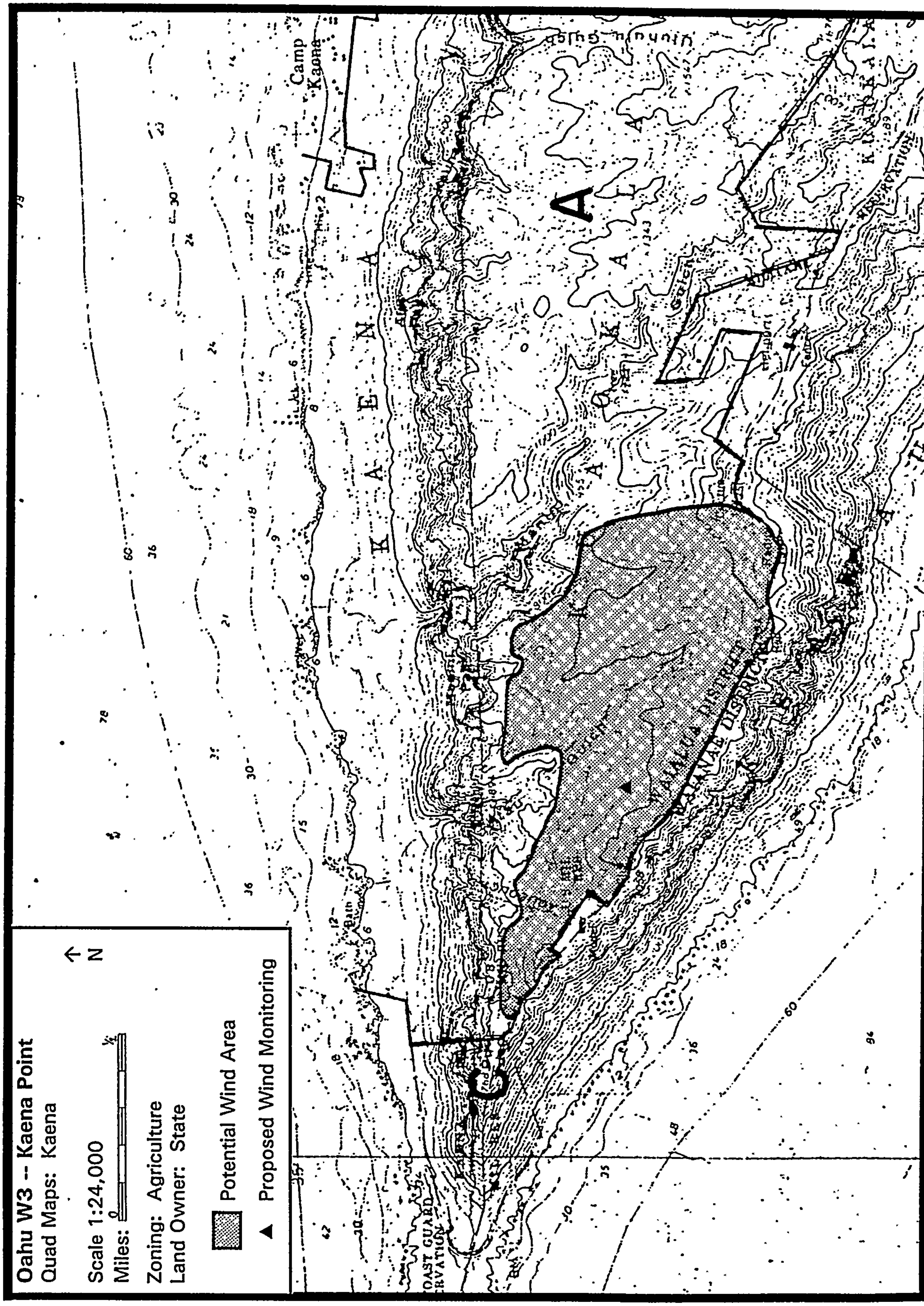
OAHU SITE MAPS

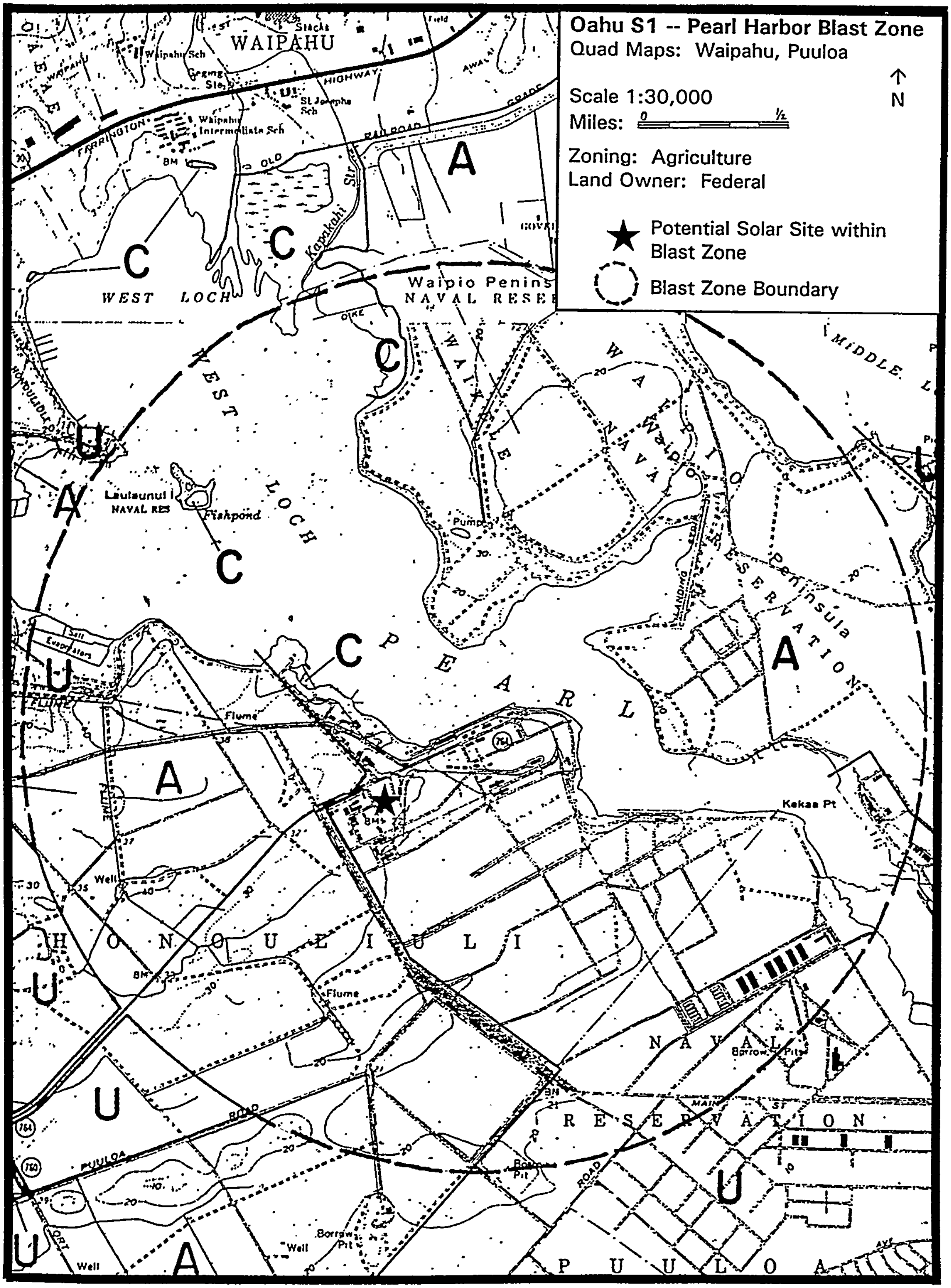
Oahu W1	Kahuku Hills
Oahu W2	Kahuku Flats
Oahu W3	Kaena Point
Oahu S1	Pearl Harbor Blast Zone
Oahu S2	North Ewa Plain
Oahu S3	Lualualei
Oahu O1	Kahe Point

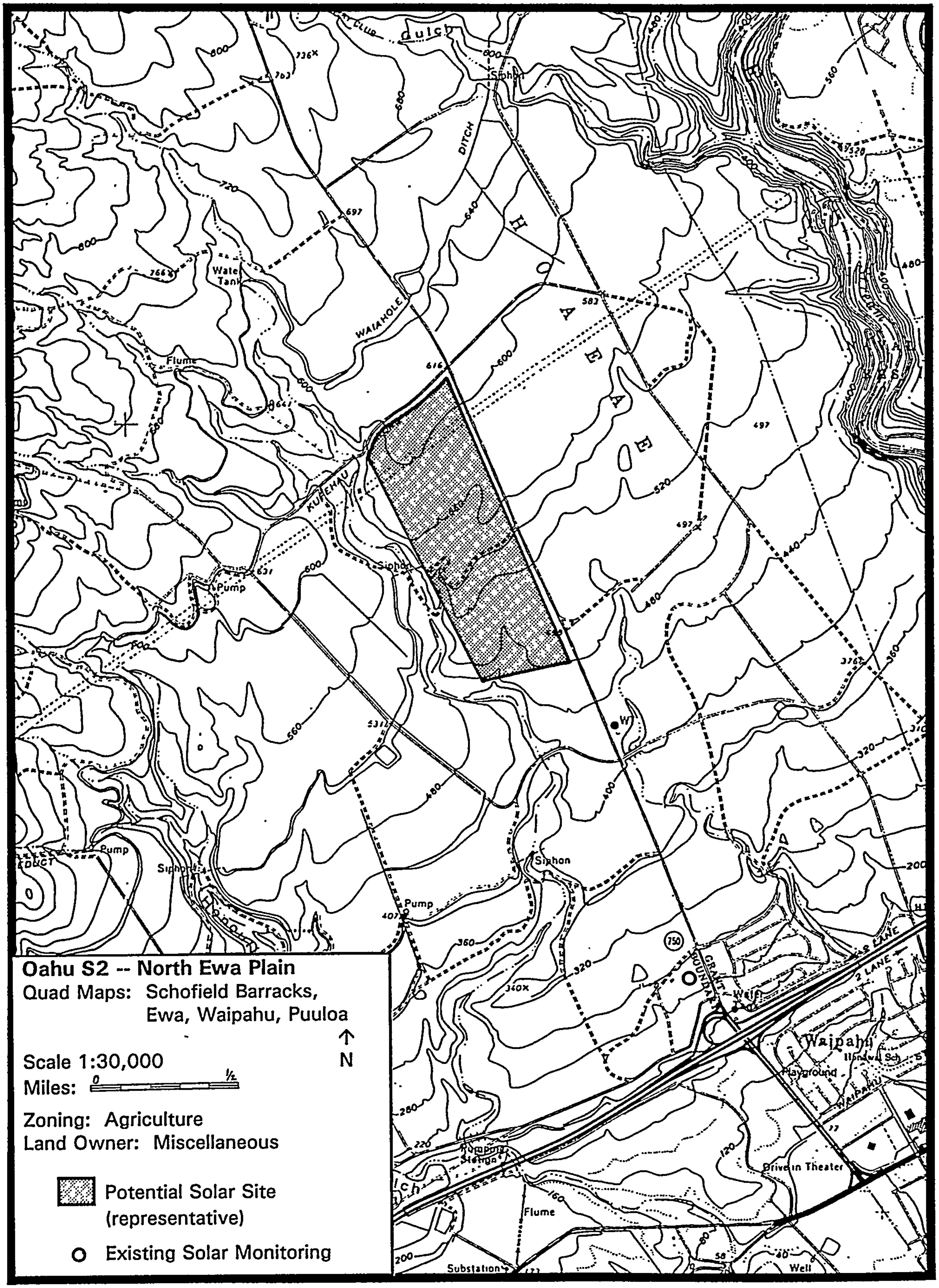


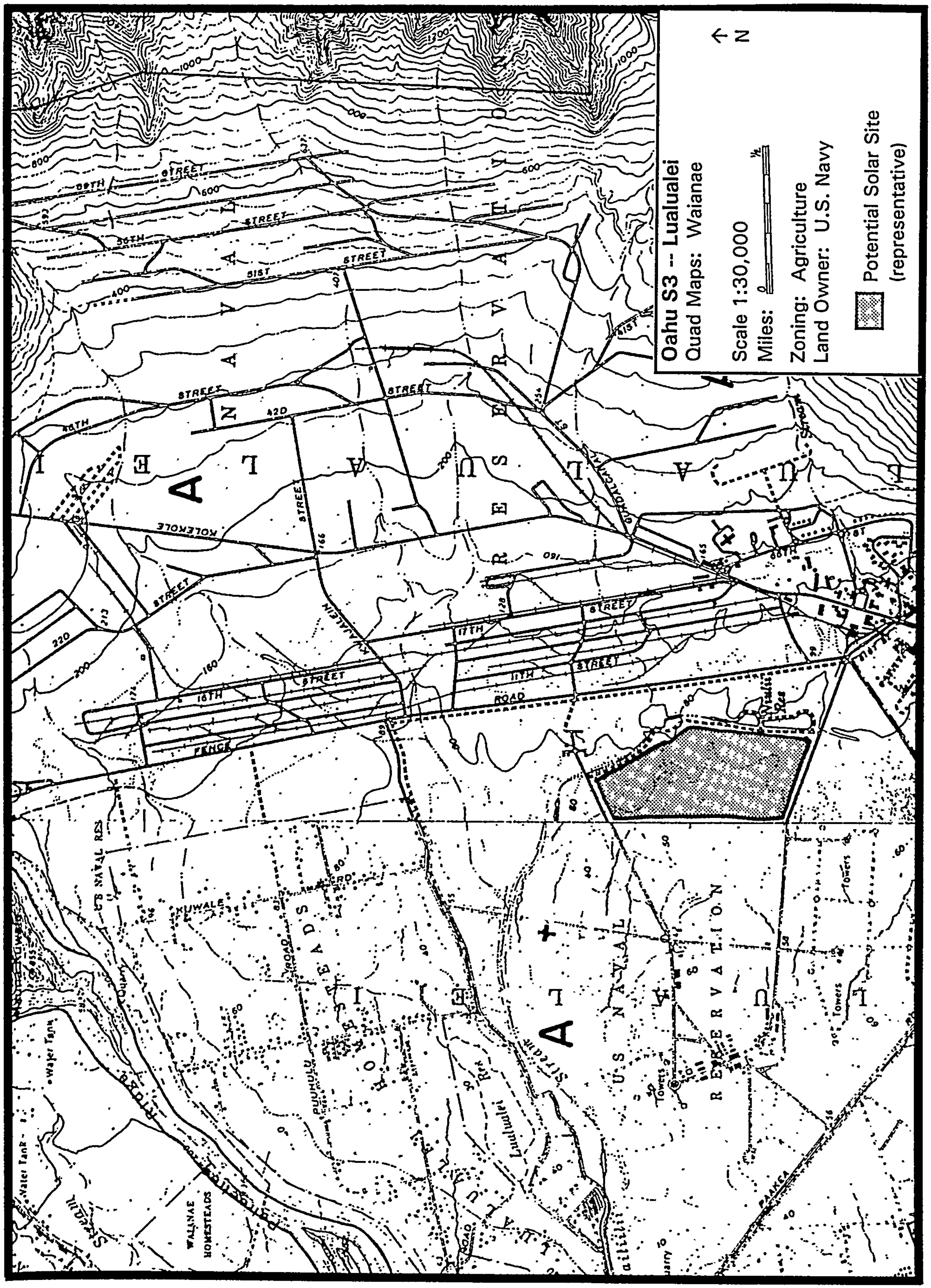
Kahuku Pt
Coral Reef
Radio Station
Landing Strip
Golf Course
Kuilima
Old Railroad Grade
Punahoolapa
Punamano
Nat Wildlife Refuge
Punamano Spring
Kawela Bay
Kawela
Kawela Stream
Well
U.S. Military Reservation
Radio Towers
Hoolapa Gulch
Siphon
Oahu W1 -- Kahuku Hills
Quad Maps: Kahuku
N
Scale 1:30,000
Miles:
Zoning: Agriculture
Land Owner: Campbell
Existing Wind Site
Existing Wind Monitoring

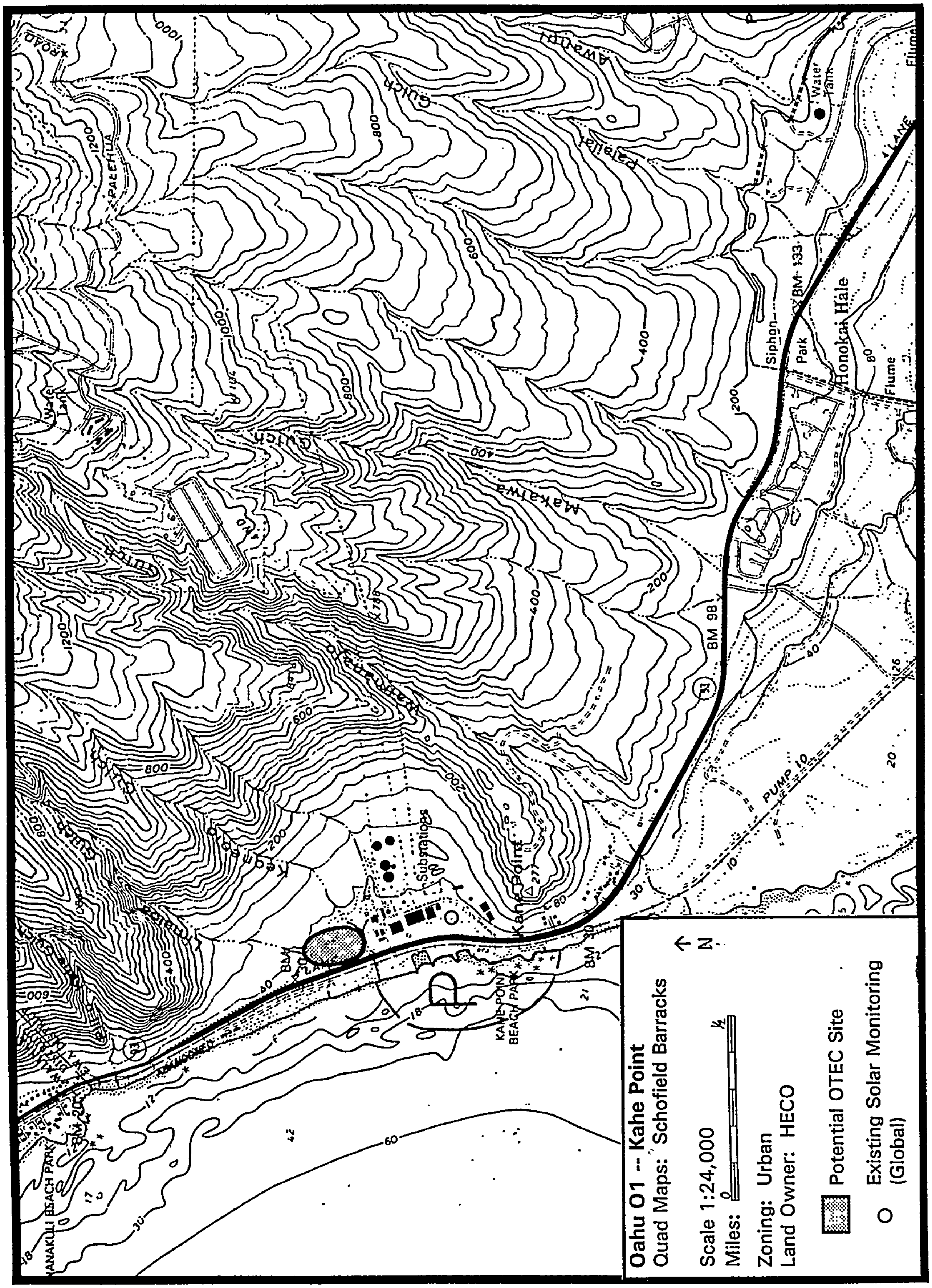

Oahu W2 -- Kahuku Flats
Quad Maps: Kahuku
N
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Campbell
Potential Wind Area
Proposed Wind Monitoring
Coral Reef
Radio Station
Anchor
Punamano
NAT WILDLIFE REFUGE
Punamano Spring
BM 19
Gulch
Well
BM 24
Ki'i
NAT WILDLIFE REFUGE
Golf Course
Kahuku
Kahuku
Hospital
Radio Tower
Siphon
83


Oahu W3 -- Kaena Point
Quad Maps: Kaena
Scale 1:24,000
Miles: 0 ½
N
Zoning: Agriculture
Land Owner: State
Potential Wind Area
Proposed Wind Monitoring
Camp Kaena
WAIALUA DISTRICT
WAIANAE DISTRICT


Oahu S1 -- Pearl Harbor Blast Zone
Quad Maps: Waipahu, Puuloa
N
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Federal
Potential Solar Site within Blast Zone
Blast Zone Boundary
WAIPAHU
WEST LOCH
Waipio Penins
NAVAL RESE
WEST LOCH
PEARL
Waipio Peninsula
NAVAL RESERVATION
HONOULIULI
NAVAL RESERVATION
PUULOA
Kekaa Pt
Laulaunui I
NAVAL RES
Fishpond
Flume
Well
Pump
MIDDLE L
A
C
U


Oahu S2 -- North Ewa Plain
Quad Maps: Schofield Barracks, Ewa, Waipahu, Puuloa
N
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Miscellaneous
Potential Solar Site (representative)
Existing Solar Monitoring
Gulch
Siphon
Water Tank
WAIAHOLE
DITCH
Flume
KUPEHAU
Pump
Waipahu
Playground
Drive in Theater
Substation
Well
2 LANE
Pumping Station

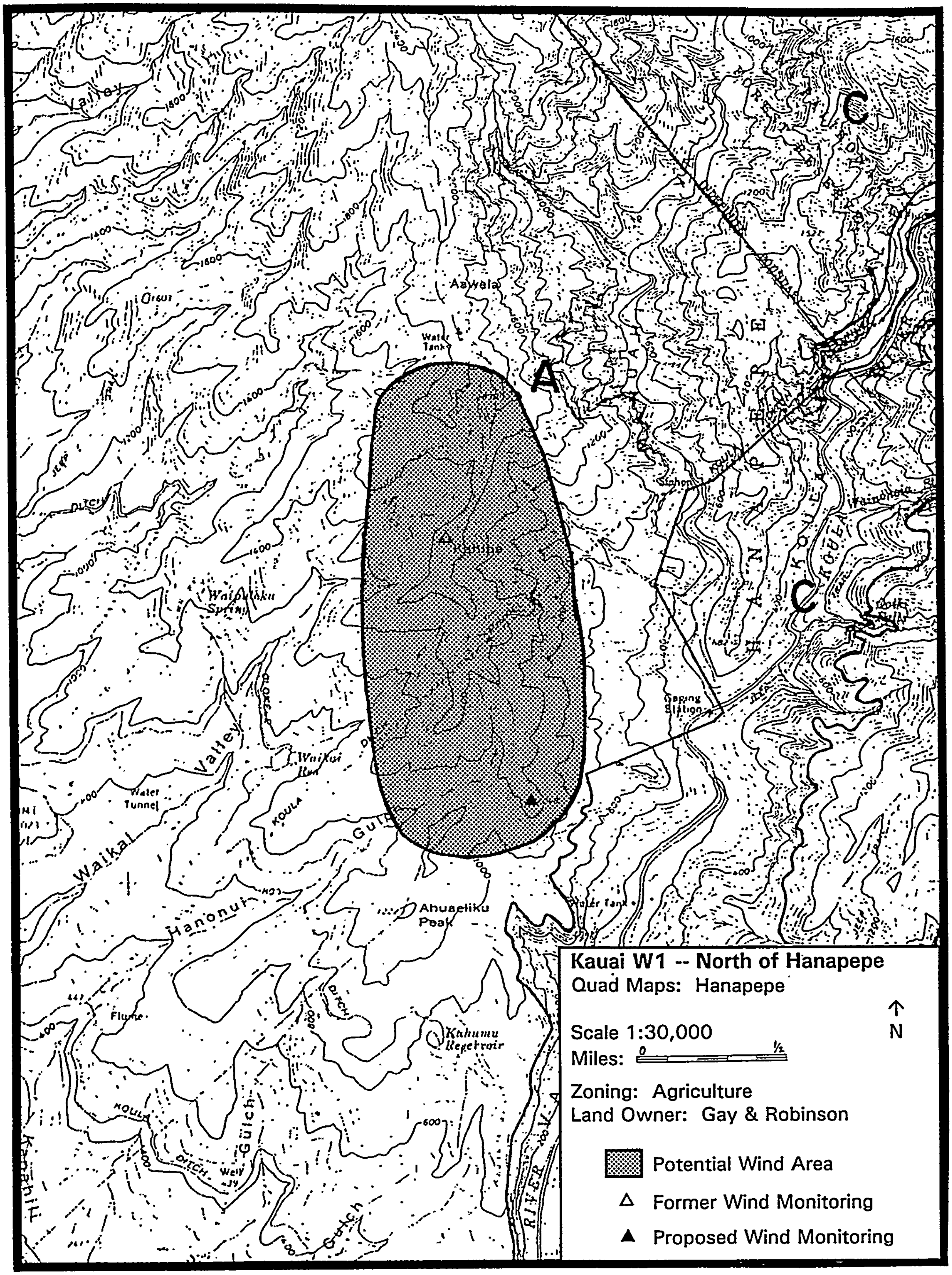

Oahu S3 -- Lualualei
Quad Maps: Waianae
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: U.S. Navy
Potential Solar Site (representative)
N


Oahu O1 -- Kahe Point
Quad Maps: Schofield Barracks
Scale 1:24,000
Miles: 0 ½
Zoning: Urban
Land Owner: HECO
Potential OTEC Site
Existing Solar Monitoring (Global)
Kahe Point
Substations
KAHE POINT BEACH PARK
NANAKULI BEACH PARK
Makaiwa
Gulch
Honokai Hale
Siphon
Park
Flume
PUMP 10
BM 98
Water Tank

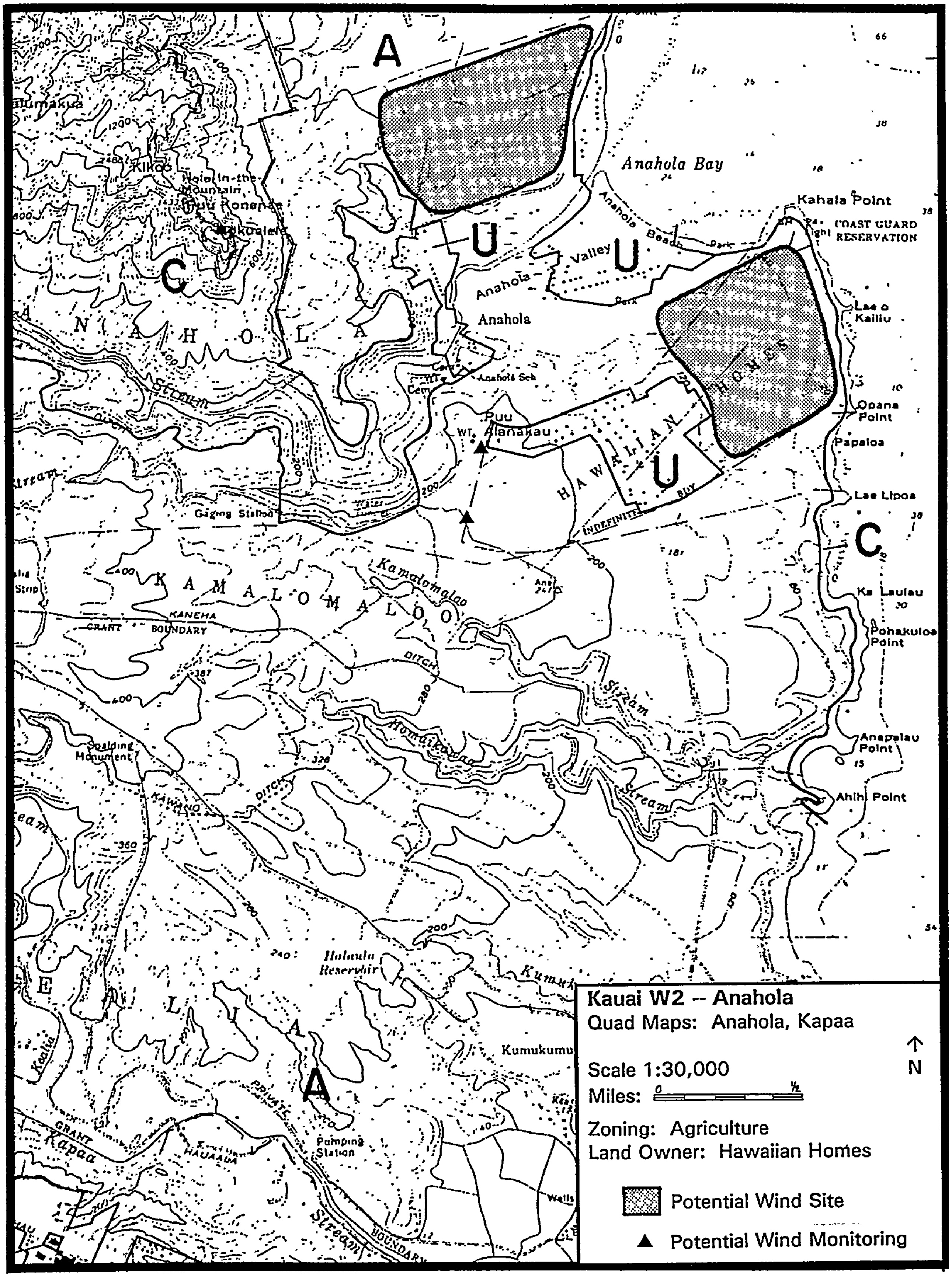
APPENDIX I

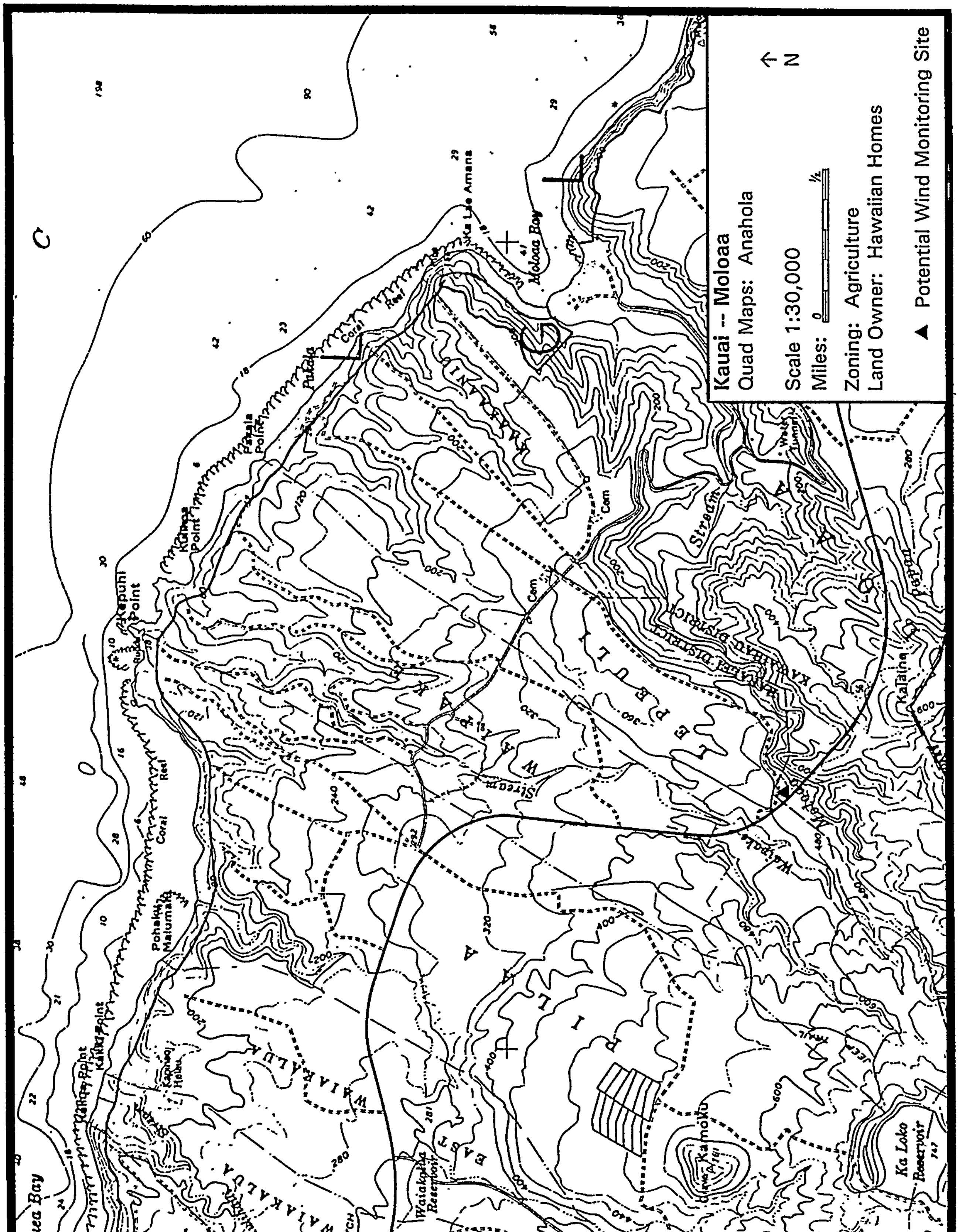
KAUAI SITE MAPS

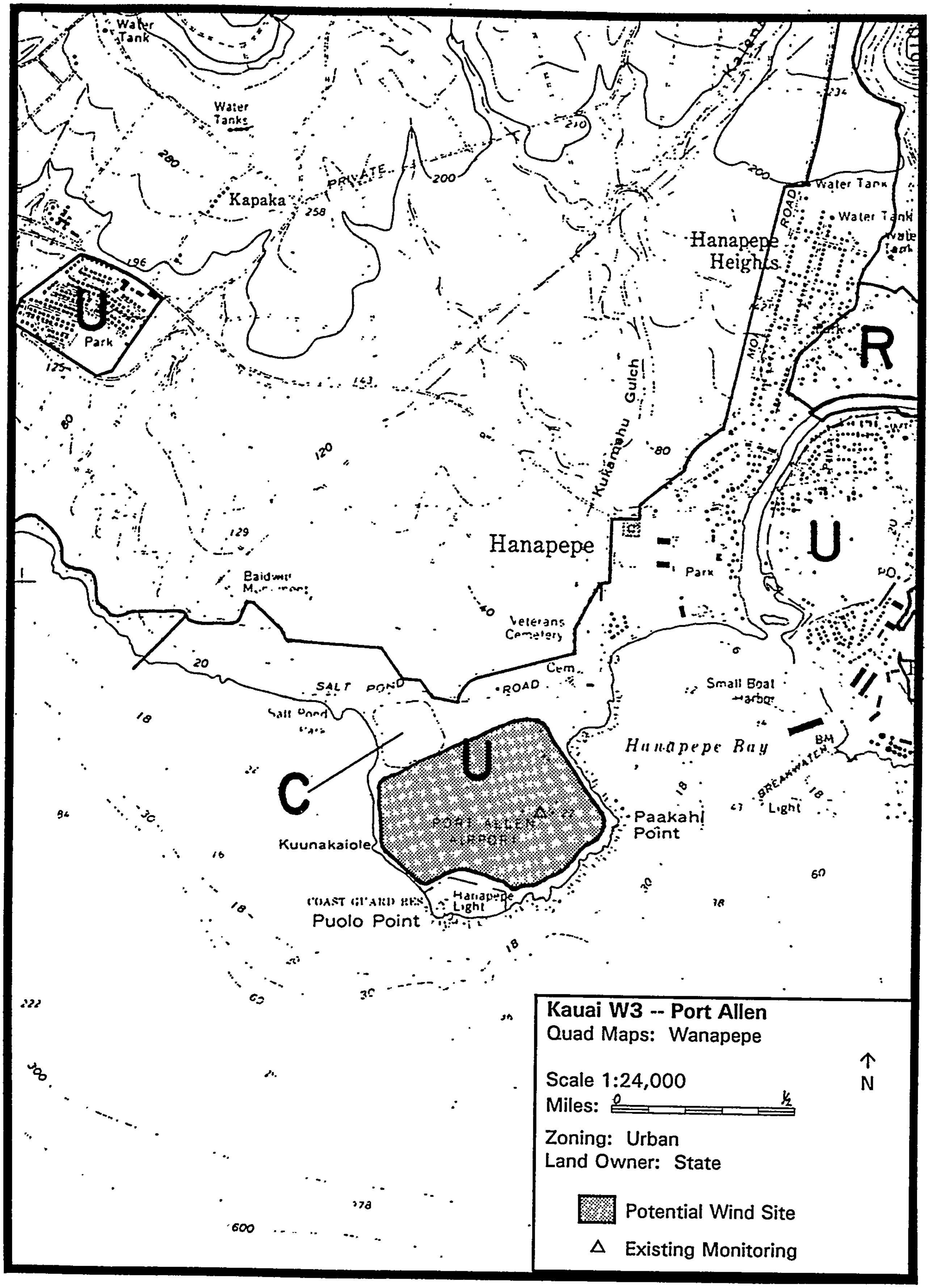
Kauai W1	North of Hanapepe
Kauai W2	Anahola
Kauai W3	South of Kilauea
Kauai S1	Barking Sands

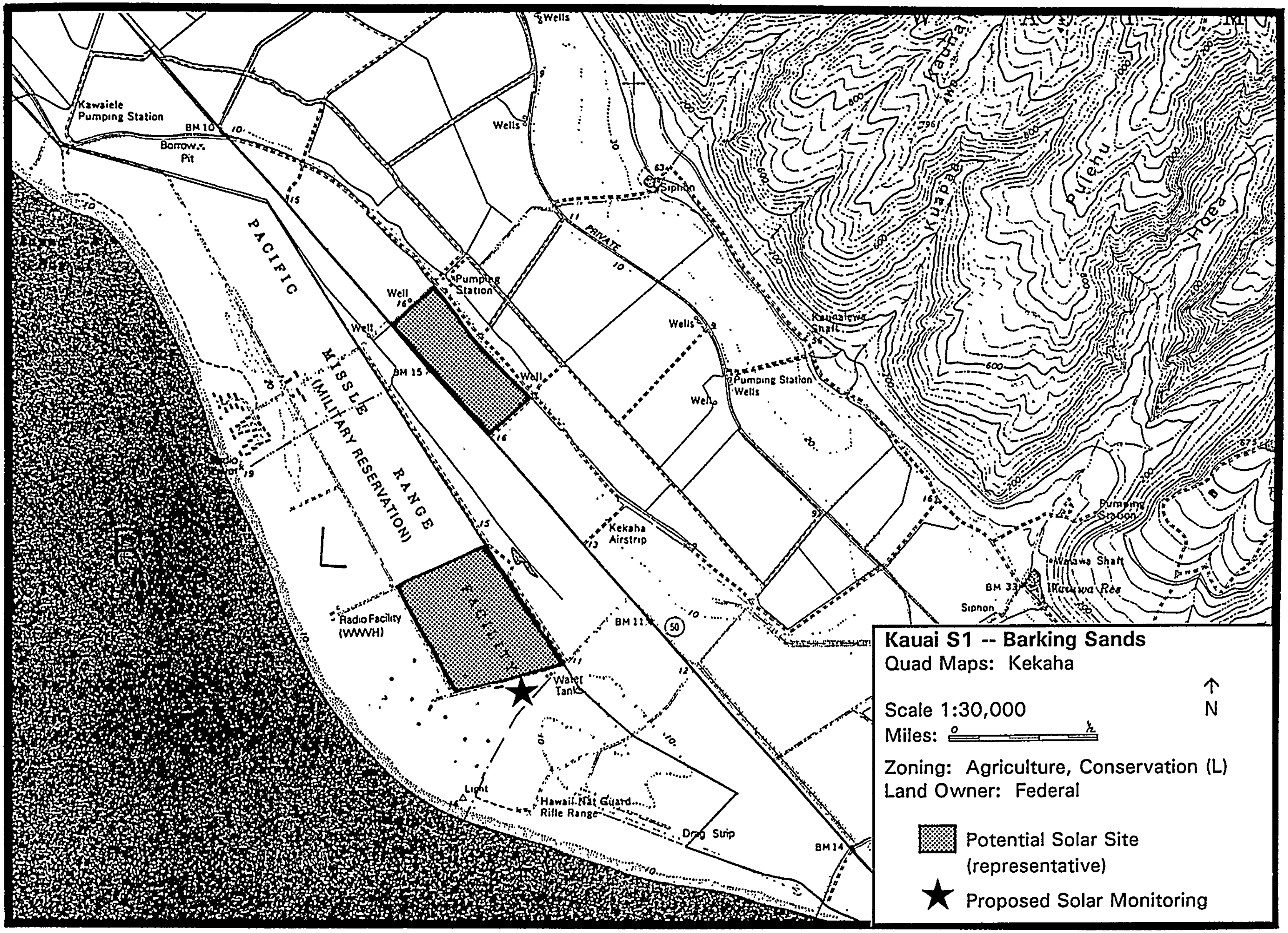


Kauai W1 -- North of Hanapepe
Quad Maps: Hanapepe
N
Scale 1:30,000
Miles:
Zoning: Agriculture
Land Owner: Gay & Robinson
Potential Wind Area
Former Wind Monitoring
Proposed Wind Monitoring
Aawela
Water Tank
Ahuaeliku Peak
Waipuhaku Spring
Water Tunnel
Waikai Valley
Hanonui Gulch
Kahumu Reservoir
Flume
Gaging Station
Siphon


A
U
U
U
C
C
A
Anahola Bay
Kahala Point
COAST GUARD RESERVATION
Anahola Beach Park
Valley
Anahola
Anahola
Lae o Kailiu
Opana Point
Papaloa
Lae Lipoa
Ka Laulau
Pohakuloa Point
Anapalau Point
Ahihi Point
ANAHOLA
Stream
Kikoo
Hole in the Mountain
Puu Alanakau
HAWAIIAN HOMES
INDEFINITE
Gaging Station
KAMALOMALOO
Kamalomaloo
KANEHA
GRANT BOUNDARY
DITCH
Stream
Homaikawaa
Stream
Spalding Monument
KAWANO
DITCH
Halaula Reservoir
Kumukumu
ELIA
Kealia
GRANT
Kapaa
HAUAALA
PRIVATE
Pumping Station
Stream
BOUNDARY
Wells
Kauai W2 -- Anahola
Quad Maps: Anahola, Kapaa
Scale 1:30,000
Miles: 0 ½
N
Zoning: Agriculture
Land Owner: Hawaiian Homes
Potential Wind Site
Potential Wind Monitoring

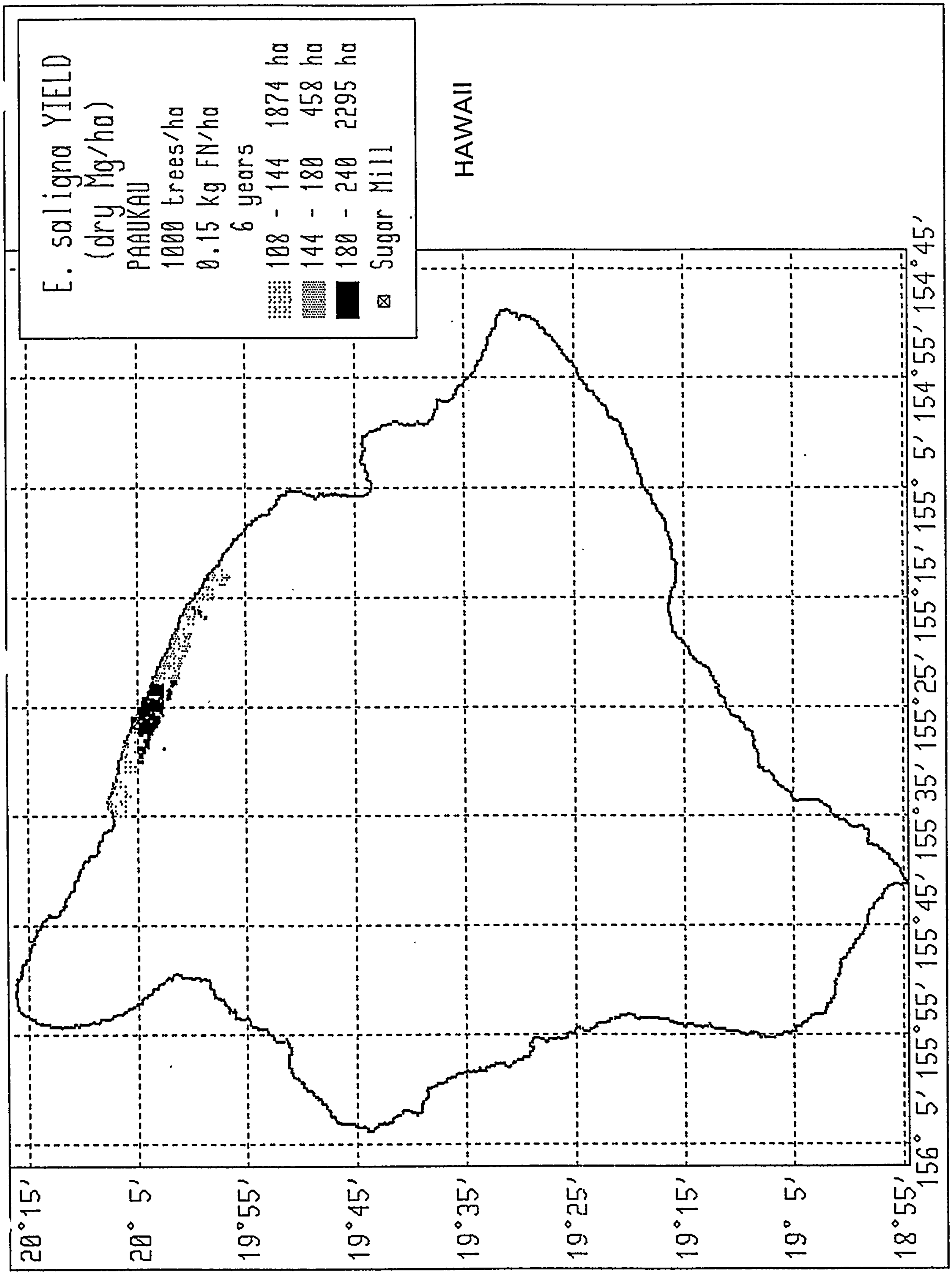

Kauai -- Moloaa
Quad Maps: Anahola
N
Scale 1:30,000
Miles: 0 ½
Zoning: Agriculture
Land Owner: Hawaiian Homes
▲ Potential Wind Monitoring Site
Kilauea Bay
Moloaa Bay
Pohakuloa Point
Kepuhi Point
Papaa Point
Coral Reef
Ka Loko Reservoir
Waiakalua Reservoir
Kalaheo District

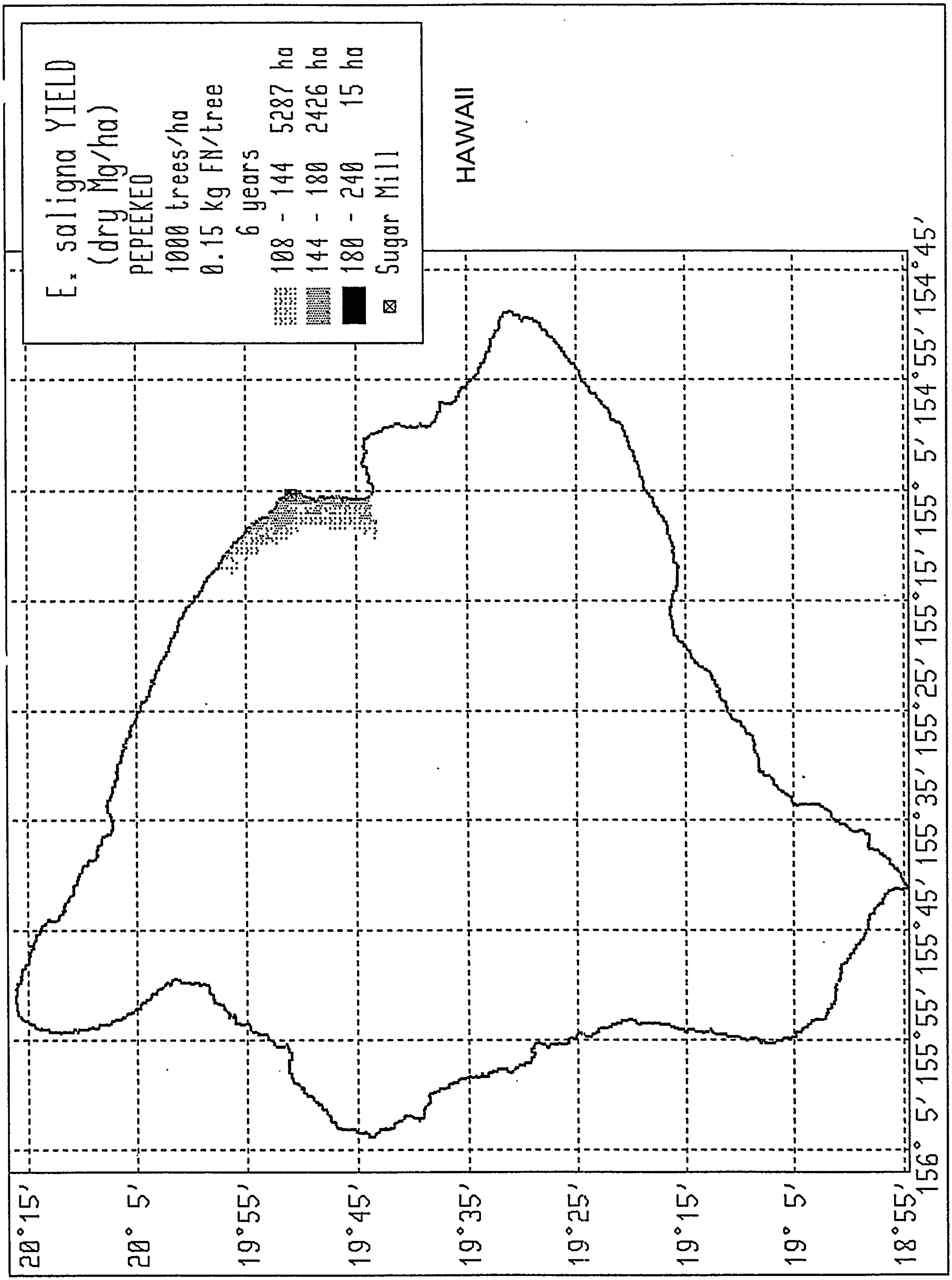

Water Tank
Water Tanks
Kapaka
PRIVATE
Hanapepe Heights
Water Tank
Water Tank
ROAD
U
Park
R
Kukamahu Gulch
Hanapepe
U
Park
Veterans Cemetery
SALT POND ROAD
Salt Pond
Cem.
Small Boat Harbor
Hanapepe Bay
BREAKWATER
Light
C
U
PORT ALLEN AIRPORT
Paakahi Point
Kuunakaiole
COAST GUARD RES
Hanapepe Light
Puolo Point
Kauai W3 -- Port Allen
Quad Maps: Wanapepe
Scale 1:24,000
Miles: 0 ½
N
Zoning: Urban
Land Owner: State
Potential Wind Site
Existing Monitoring

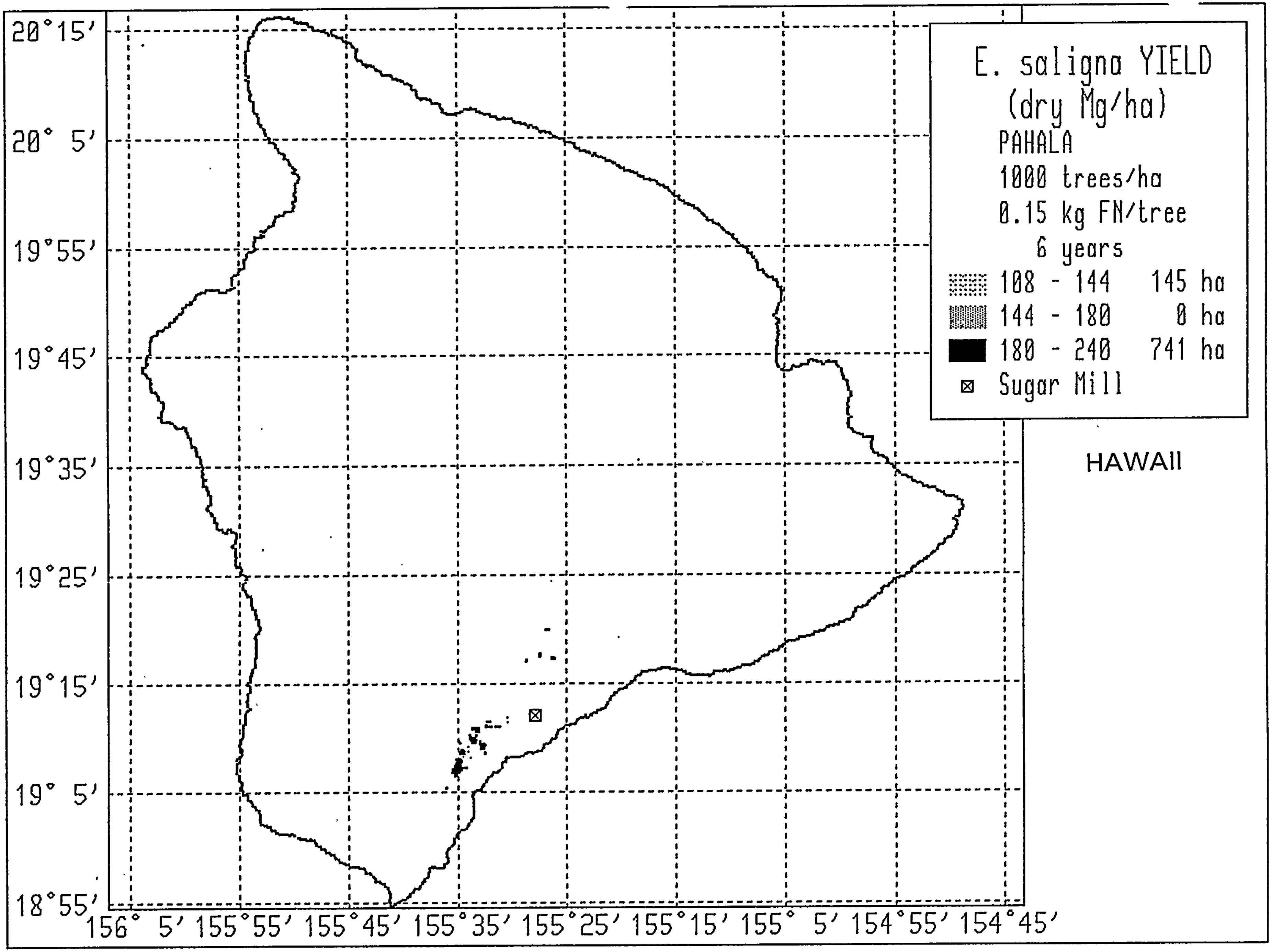

Kauai S1 -- Barking Sands
Quad Maps: Kekaha
Scale 1:30,000
Miles: 0 ½
N
Zoning: Agriculture, Conservation (L)
Land Owner: Federal
Potential Solar Site (representative)
Proposed Solar Monitoring
PACIFIC MISSLE RANGE
(MILITARY RESERVATION)
FACILITY
Kawaiele Pumping Station
BM 10
Borrow Pit
Wells
Siphon
PRIVATE
Pumping Station
Well
BM 15
Kaunalewa Shaft
Pumping Station Wells
Kekaha Airstrip
Radio Facility (WWVH)
BM 11
50
Water Tank
Light
Hawaii Nat Guard Rifle Range
Drag Strip
BM 14
BM 33
Sipnon
Pumping Station
Kapaula
Pulehu
Hoea

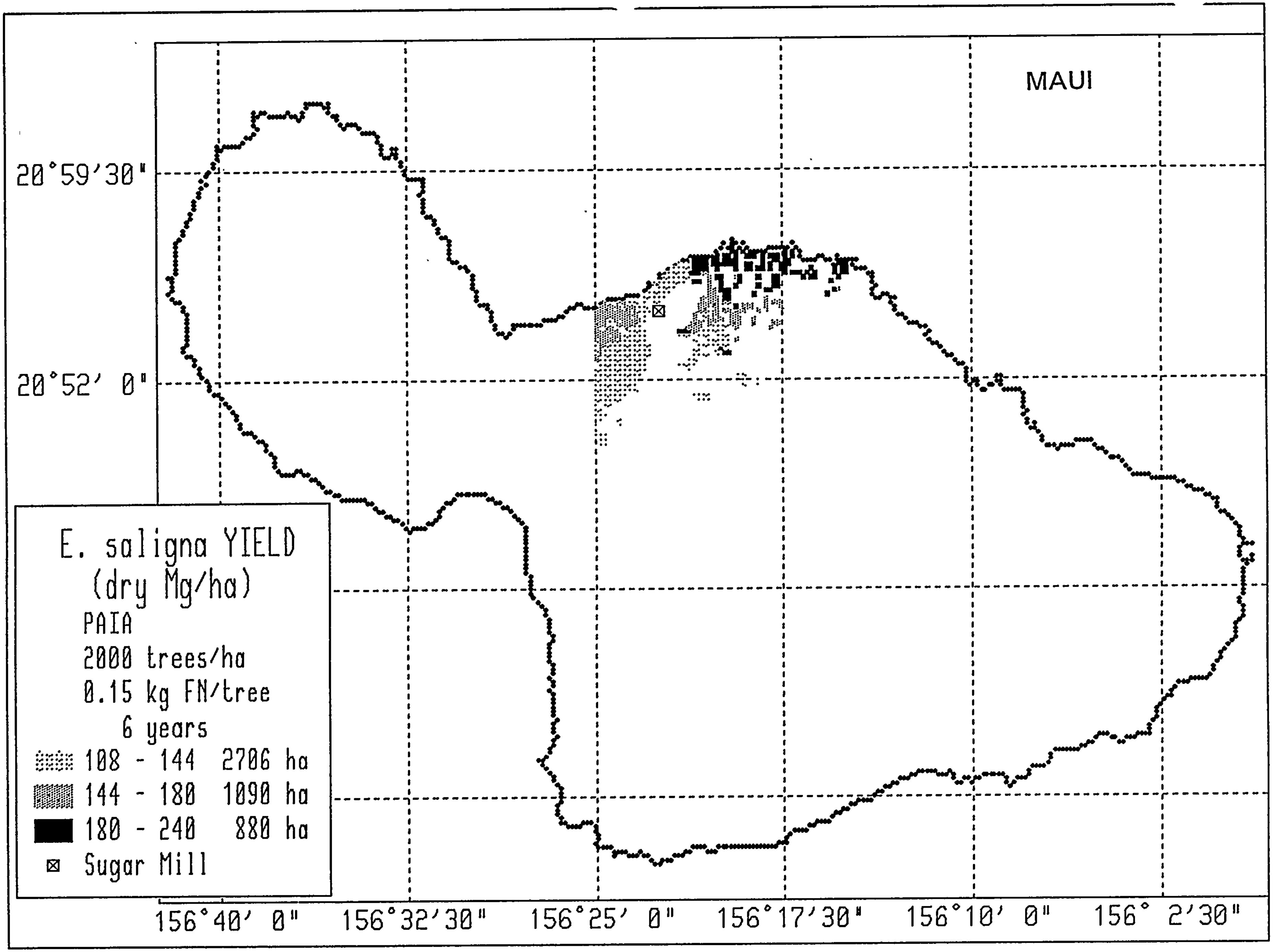
APPENDIX J

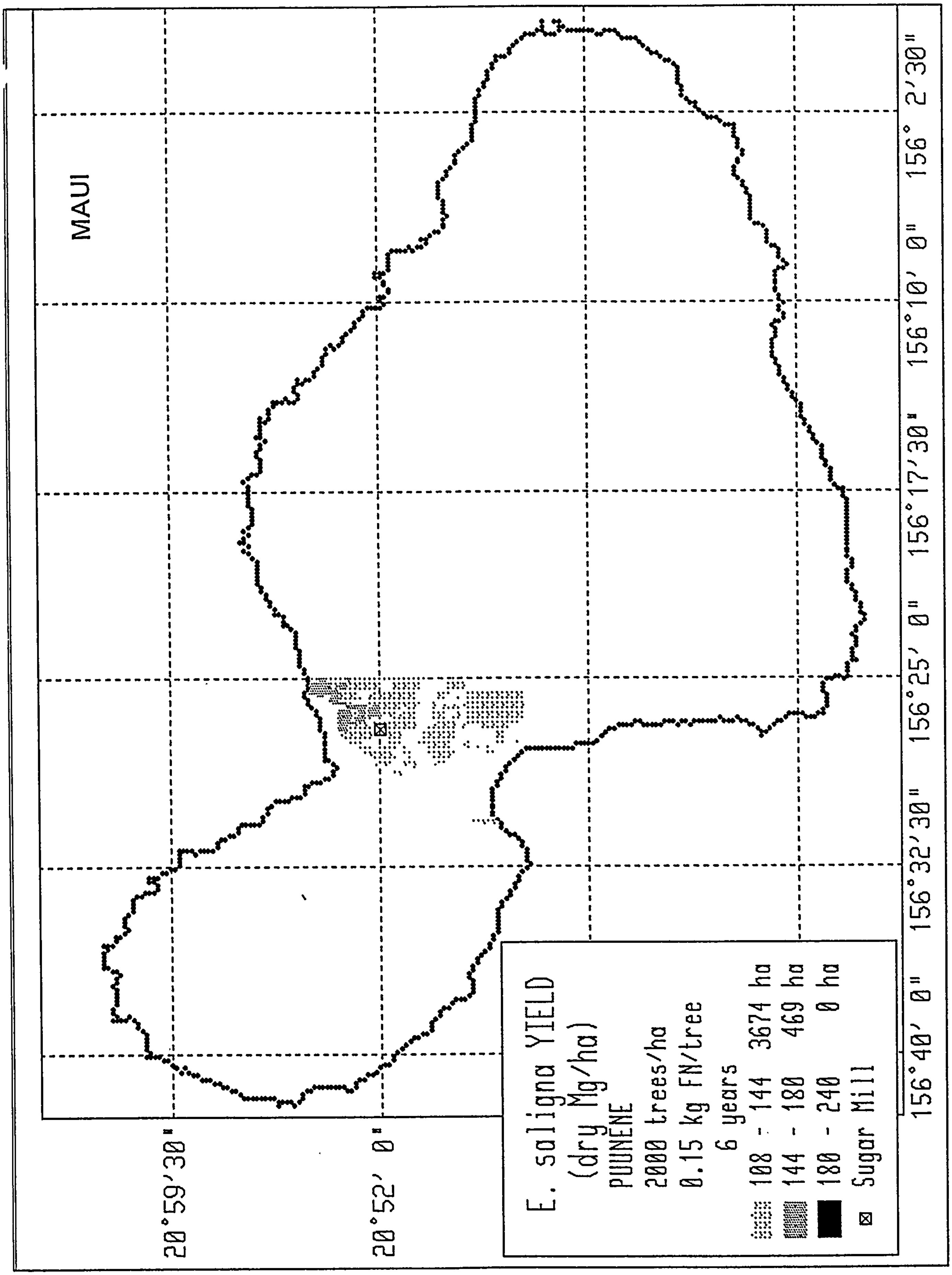
BIOMASS PROJECT MAPS

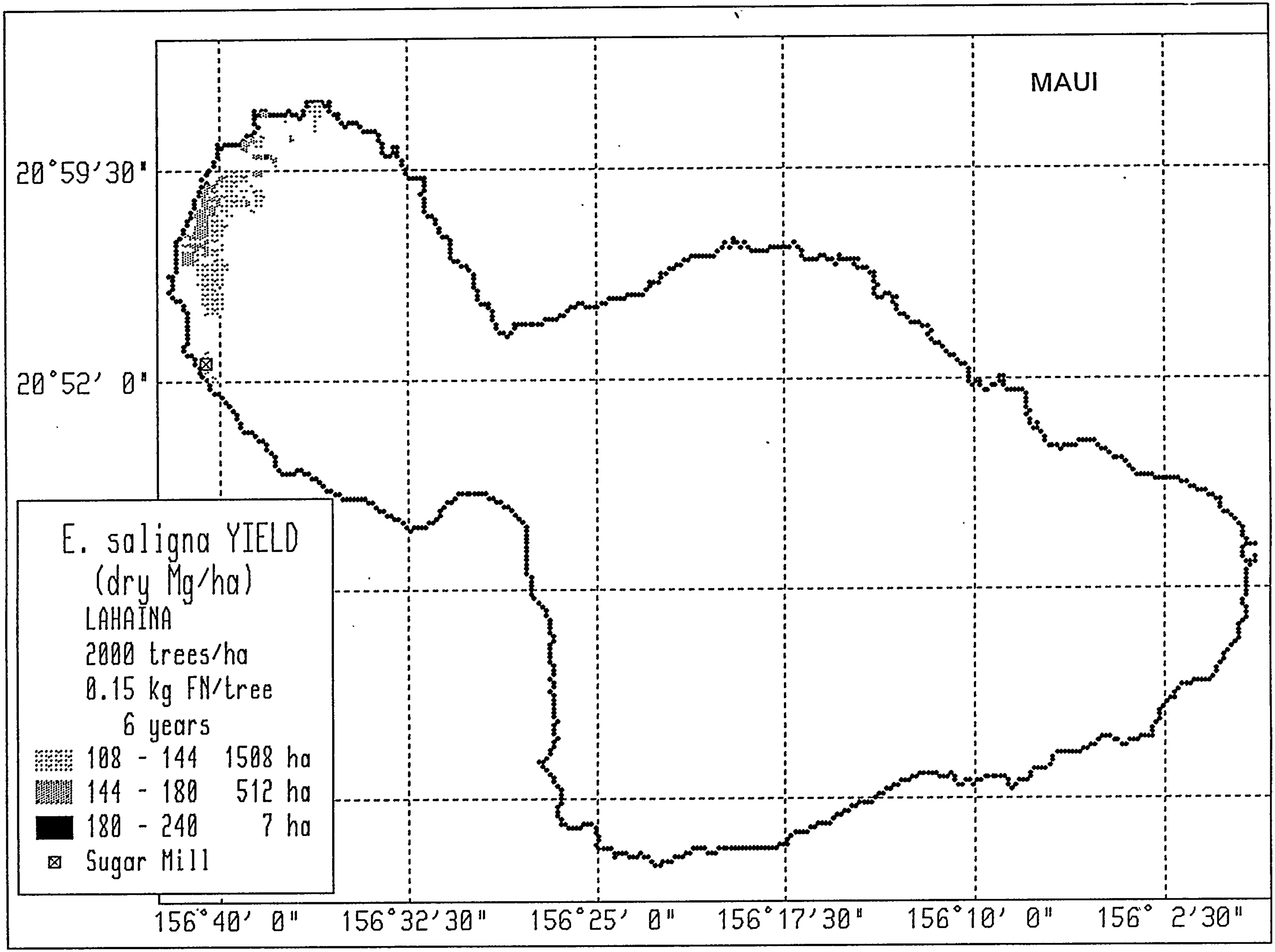

E. saligna YIELD
(dry Mg/ha)
PAAUKAU
1000 trees/ha
0.15 kg FN/ha
6 years
108 - 144 1874 ha
144 - 180 458 ha
180 - 240 2295 ha
Sugar Mill
HAWAII
20°15'
20° 5'
19°55'
19°45'
19°35'
19°25'
19°15'
19° 5'
18°55'
156° 5' 155°55' 155°45' 155°35' 155°25' 155°15' 155° 5' 154°55' 154°45'

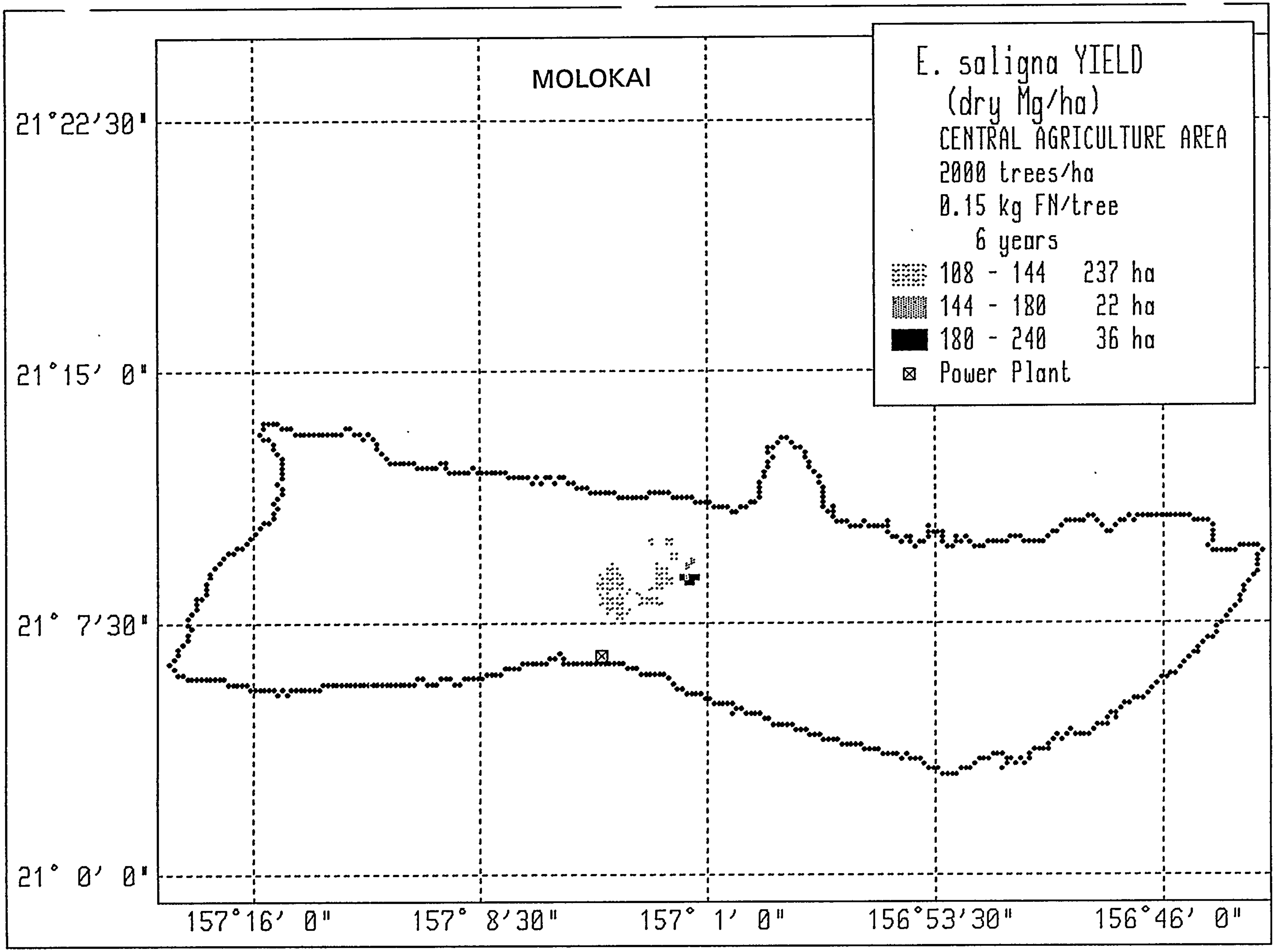

E. saligna YIELD
(dry Mg/ha)
PEPEEKEO
1000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 5287 ha
144 - 180 2426 ha
180 - 240 15 ha
Sugar Mill
HAWAII
20°15'
20° 5'
19°55'
19°45'
19°35'
19°25'
19°15'
19° 5'
18°55'
156°
5'
155°55'
155°45'
155°35'
155°25'
155°15'
155° 5'
154°55'
154°45'

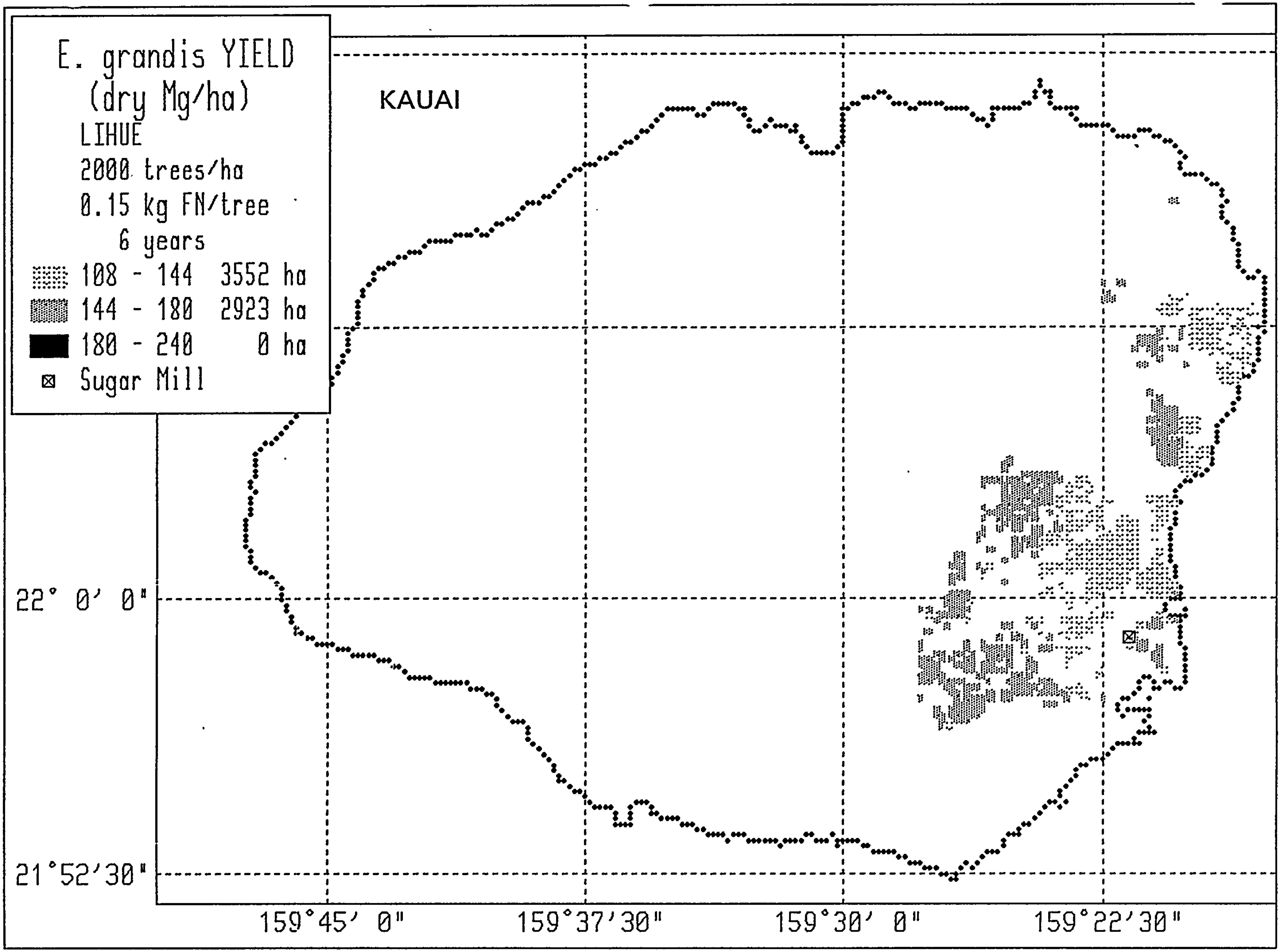

E. saligna YIELD
(dry Mg/ha)
PAHALA
1000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 145 ha
144 - 180 0 ha
180 - 240 741 ha
Sugar Mill
HAWAII
20°15′
20° 5′
19°55′
19°45′
19°35′
19°25′
19°15′
19° 5′
18°55′
156° 5′ 155°55′ 155°45′ 155°35′ 155°25′ 155°15′ 155° 5′ 154°55′ 154°45′

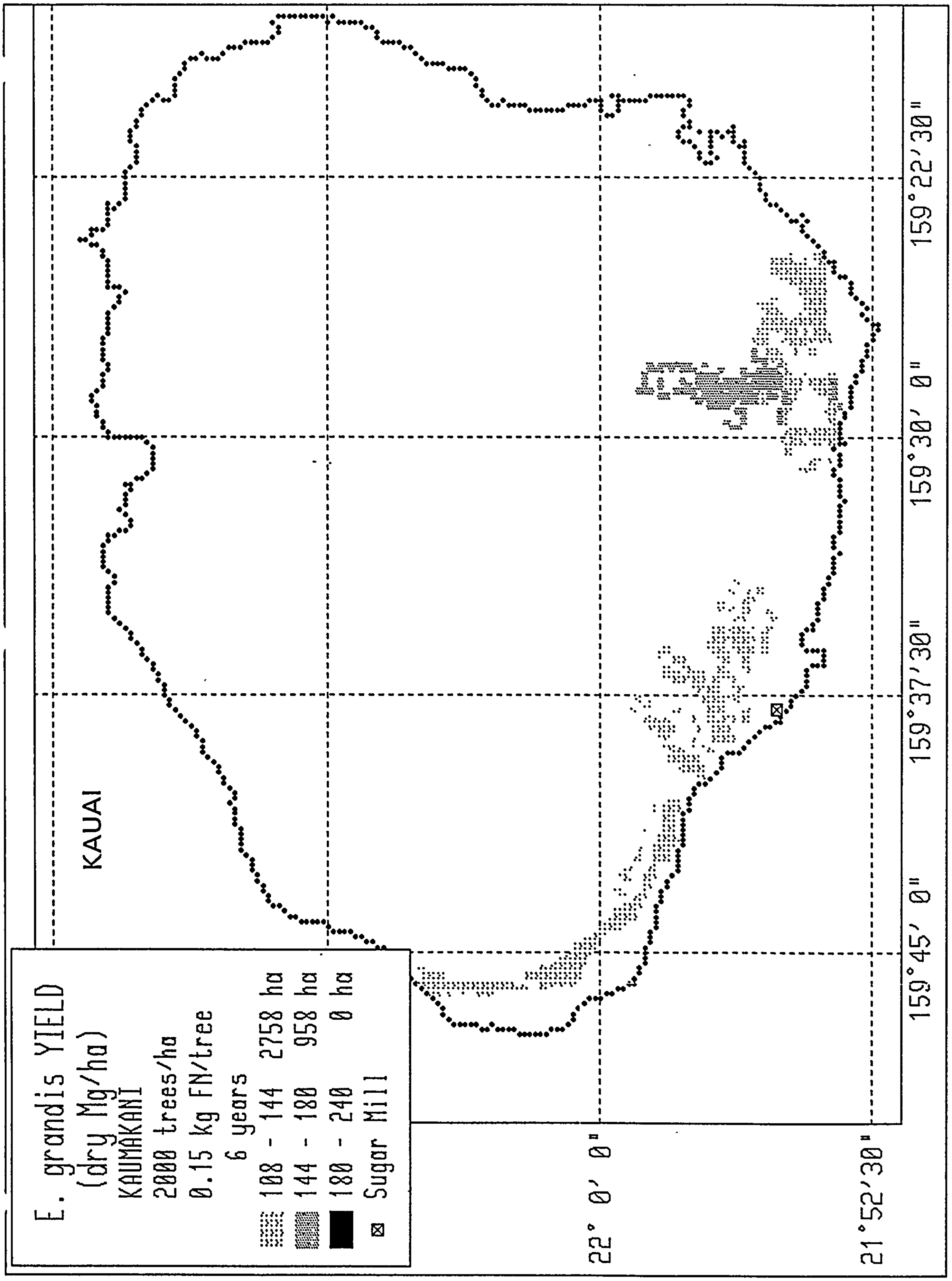

MAUI
20°59'30"
20°52' 0"
156°40' 0"
156°32'30"
156°25' 0"
156°17'30"
156°10' 0"
156° 2'30"
E. saligna YIELD
(dry Mg/ha)
PAIA
2000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 2706 ha
144 - 180 1090 ha
180 - 240 880 ha
Sugar Mill


MAUI
20°59'30"
20°52' 0"
156° 2'30"
156°10' 0"
156°17'30"
156°25' 0"
156°32'30"
156°40' 0"
E. saligna YIELD
(dry Mg/ha)
PUUNENE
2000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 3674 ha
144 - 180 469 ha
180 - 240 0 ha
Sugar Mill


MAUI
20°59'30"
20°52' 0"
156°40' 0"
156°32'30"
156°25' 0"
156°17'30"
156°10' 0"
156° 2'30"
E. saligna YIELD
(dry Mg/ha)
LAHAINA
2000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 1508 ha
144 - 180 512 ha
180 - 240 7 ha
Sugar Mill


MOLOKAI
E. saligna YIELD
(dry Mg/ha)
CENTRAL AGRICULTURE AREA
2000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 237 ha
144 - 180 22 ha
180 - 240 36 ha
Power Plant
21°22'30"
21°15' 0"
21° 7'30"
21° 0' 0"
157°16' 0"
157° 8'30"
157° 1' 0"
156°53'30"
156°46' 0"


E. grandis YIELD
(dry Mg/ha)
LIHUE
2000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 3552 ha
144 - 180 2923 ha
180 - 240 0 ha
Sugar Mill
KAUAI
22° 0′ 0"
21°52′30"
159°45′ 0"
159°37′30"
159°30′ 0"
159°22′30"



KAUAI
E. grandis YIELD
(dry Mg/ha)
KAUMAKANI
2000 trees/ha
0.15 kg FN/tree
6 years
108 - 144 2758 ha
144 - 180 958 ha
180 - 240 0 ha
Sugar Mill
22° 0' 0"
21°52'30"
159°45' 0"
159°37'30"
159°30' 0"
159°22'30"

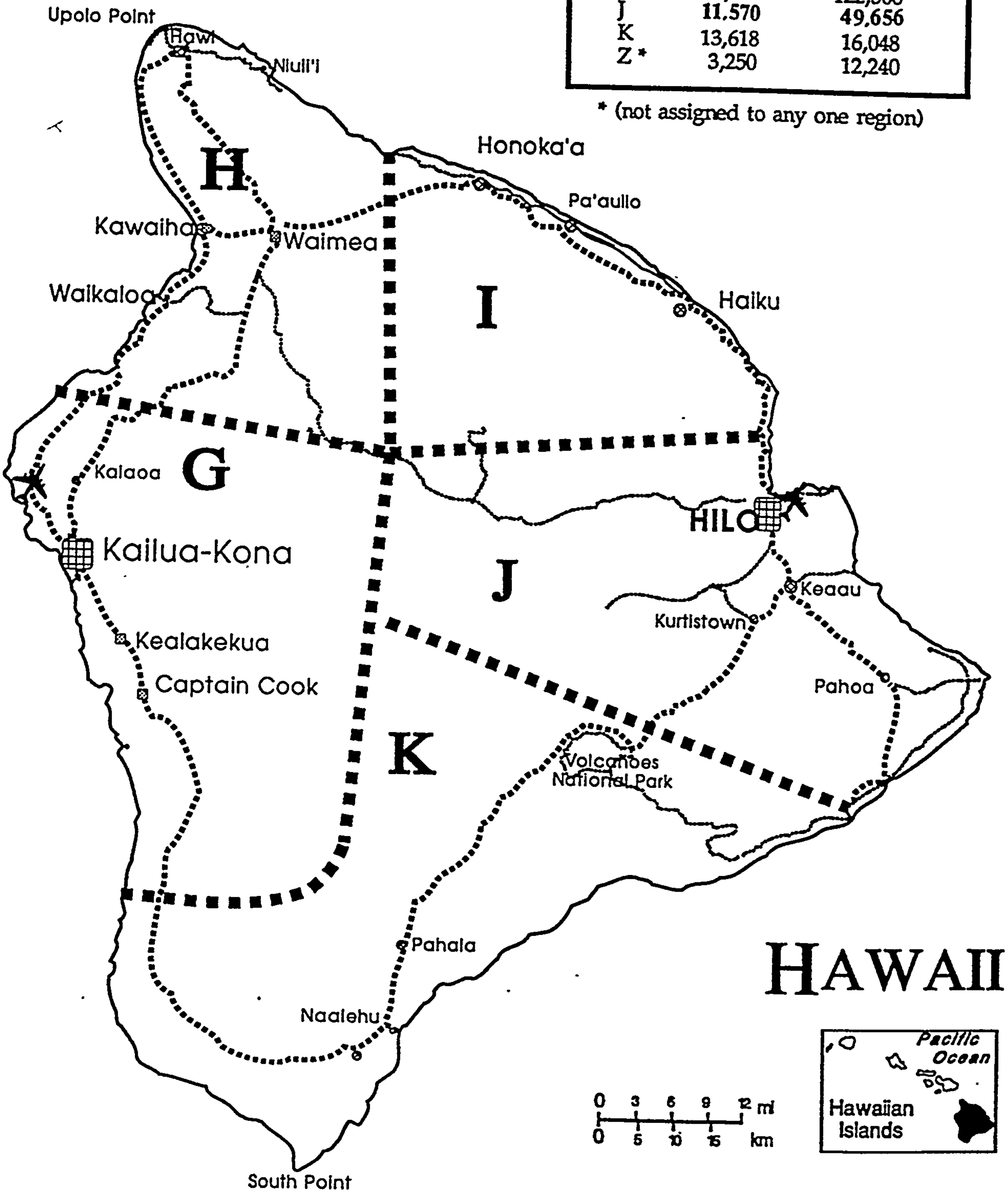
HAWAII

REGIONAL ESTIMATES OF ORGANIC WASTE PRODUCTION
(tons per year)

Source: Unisyn Biowaste Technology, 1993.

REGION	SURVEYED	OPPORTUNITY
G	9,249	28,564
H	25,044	41,519
I	118,115	122,306
J	11.570	49,656
K	13,618	16,048
Z *	3,250	12,240

* (not assigned to any one region)

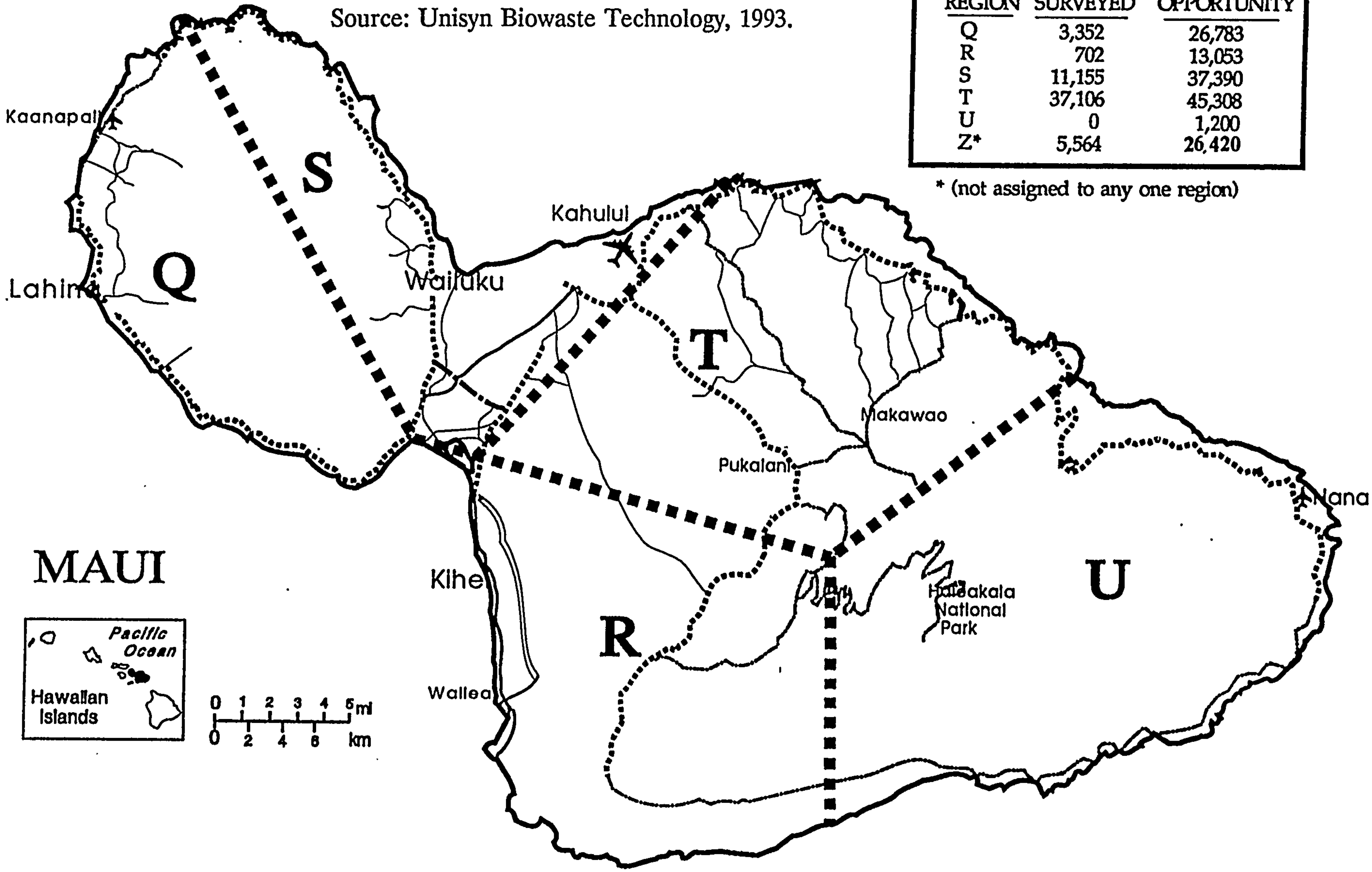


MAUI
REGIONAL ESTIMATES of ORGANIC WASTE PRODUCTION
(tons per year)

Source: Unisyn Biowaste Technology, 1993.

REGION	SURVEYED	OPPORTUNITY
Q	3,352	26,783
R	702	13,053
S	11,155	37,390
T	37,106	45,308
U	0	1,200
Z*	5,564	26,420

* (not assigned to any one region)

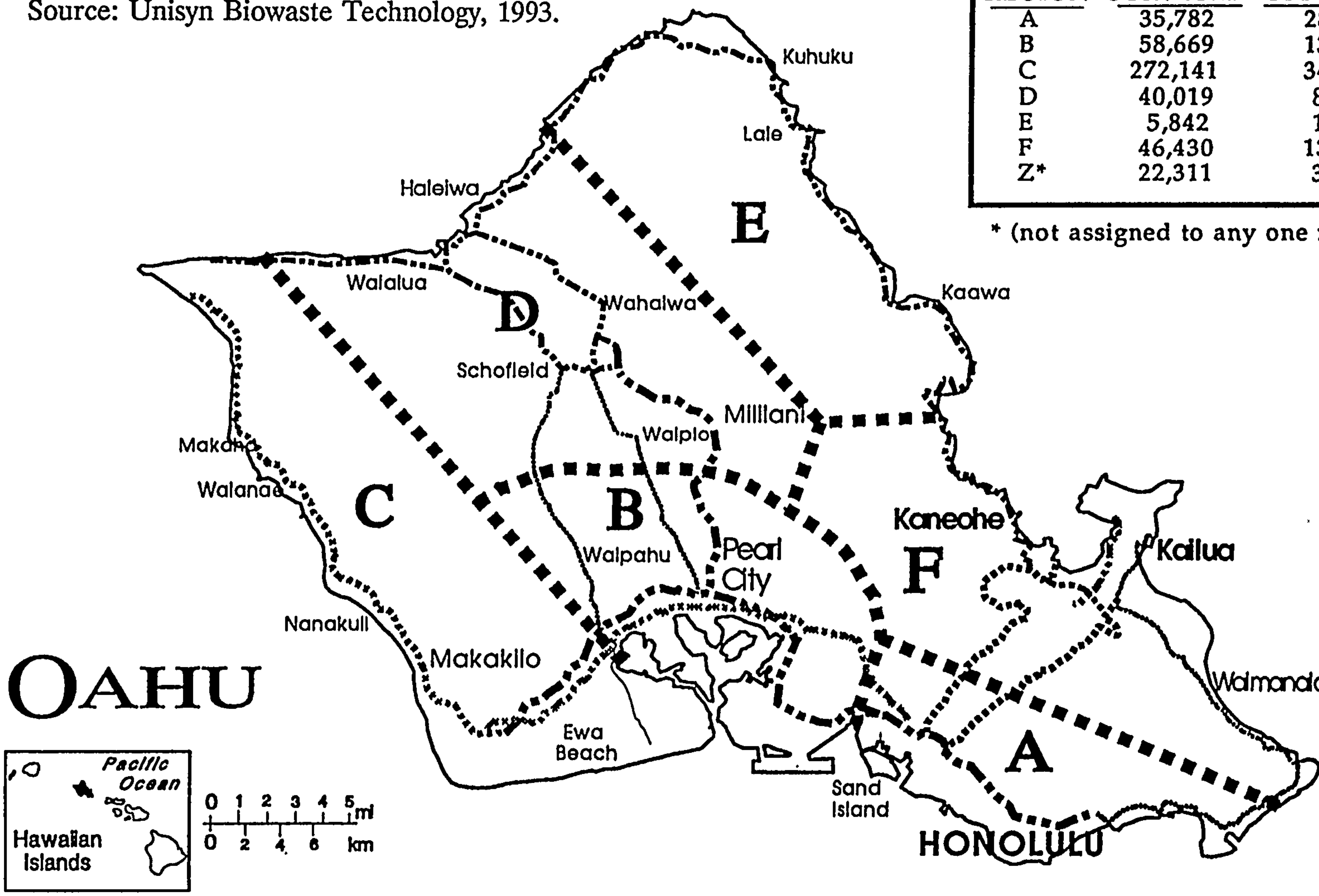


CITY & COUNTY of HONOLULU
REGIONAL ESTIMATES of ORGANIC WASTE PRODUCTION
(tons per year)

Source: Unisyn Biowaste Technology, 1993.

REGION	SURVEYED	OPPORTUNITY
A	35,782	282,214
B	58,669	137,160
C	272,141	346,046
D	40,019	89,812
E	5,842	18,121
F	46,430	131,424
Z*	22,311	38,520

* (not assigned to any one region)

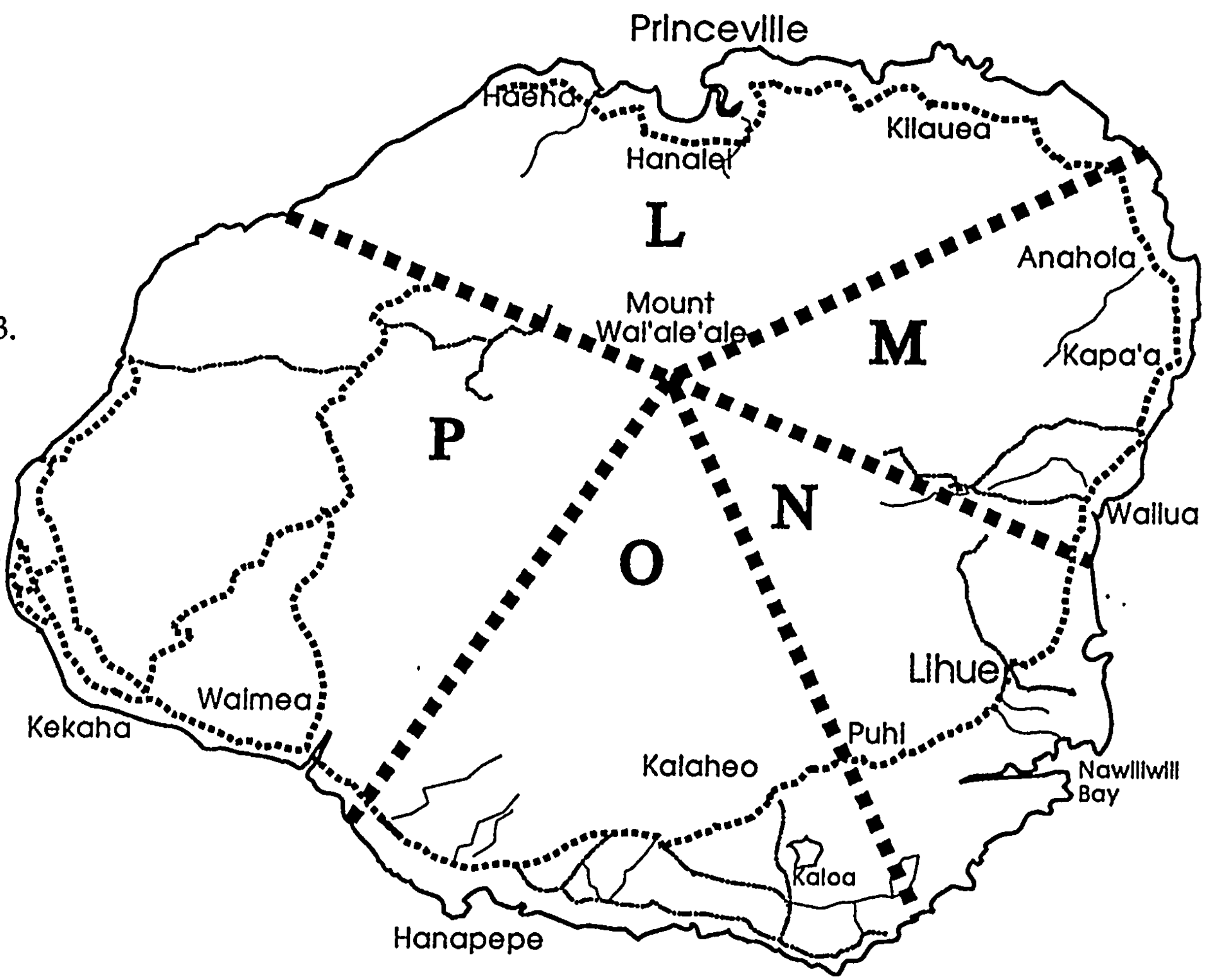


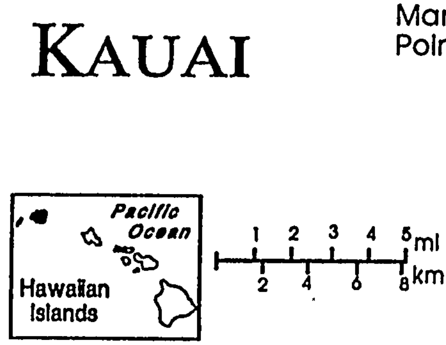
KAUAI
REGIONAL ESTIMATES of ORGANIC WASTE PRODUCTION
(tons per year)

REGION	SURVEYED	OPPORTUNITY
L	5,000	9,095
M	.19,946	30,203
N	3,680	14,396
O	26,469	35,553
P	96	5,136
Z*	0	6,840

* (not assigned to any one region)

Source: Unisyn Biowaste Technology, 1993.





APPENDIX K

EQUIPMENT SPECIFICATIONS AND QUOTES

NRG Systems
110 Commerce Street, Hinesburg, VT 05461 USA • (802) 482-2255 • FAX (802) 482-2272 • TELEX 650-313-4621 MCI UW

DATE: May 28, 1992

TO: Robert Poore
R. LYNETTE & ASSOCIATES
15042 NE 40th Street
Suite 206
Redmond
WA

FAX #: 206-881-8468
PHONE #: 206-885-0206

FROM: Gregory Erdmann, International Sales

NUMBER OF PAGES INCLUDING COVER: 1

SUBJECT: NRG SYSTEM-1

Robert,

Please excuse the lateness of this fax, I had been waiting on better shipping prices to Hawaii. There are two reasons why I write this letter to you:

1) NRG Systems hereby grants R. Lynette and Associates a 10% discount on all equipment bought directly though us. You may add the standard quantity discounts as well as the usual 5% prepayment discount on top of this.

2) A "ballpark" figure on your two request for complete NRG Systems wind measuring stations with the option of two different heights:

a) Shipping 10 SYSTEM-1 (10 Meter TallTowers) to Honolulu, Hawaii: Approximately: $625.00

b) Shipping 10 SYSTEM-1 (30 Meter TallTowers) to Honolulu, Hawaii: Approximately: $1850.00

Please notice the next page for a description of our SYSTEM-1, it is basically what you requested. If you need a more detailed quotation, I will happy to send one to you. In fact, I would prefer to send you an official quotation when you decide on your exact requirements.

I look forward to hearing from you,

Sincerely,

Gregory S. Erdmann
International Sales Director

NRG Systems
110 Commerce Street, Hinesburg, VT 05461 USA • (802) 482-2255 • FAX (802) 482-2272 • TELEX 650-313-4621 MCI UW

NRG SYSTEMS PRICE LIST: U.S.A. & CANADA

October 1992

9200 Series NRG Loggers

All 9200 NRG Loggers include (2) 9V batteries, (1) 64K DataChip, 60' cable per sensor, and mounting stub masts. All speed and direction sensors are included according to model number. Please specify cable length requirements.

MODEL #		PRICE
9200-00	NO SENSORS	$950.00
9200-01	1 SPEED	1050.00
9200-11	1 SPEED, 1 DIRECTION	1220.00
9200-21	2 SPEED, 1 DIRECTION	1320.00
9200-22	2 SPEED, 2 DIRECTION	1480.00
PAK-2	DATALOG2 DATA ANALYSIS SOFTWARE WITH EEREADER2	970.00
PAK-1	DL9200 BASIC READING SOFTWARE	500.00

Options:
Add $120.00 per #40C Calibrated Anemometer
Add $25.00 per logger configured for 256K DataChip

9300 Series Advanced Data Acquisiton Systems

All #9300 NRG Loggers include (1) 256K Byte FLASH card, 6 pulse counting channels, and 6 analog channels. Please add the appropriate sensors below to configure your particular system.

MODEL#		PRICE	
9300SA	Stand Alone Logger	$1490.00	Includes (2) 9V alkaline batteries, (1) 256K Byte FLASH Card, no sensors
9300 CL	CELLogger Cellular Data Logger	$2470.00	Includes internal 12V battery, 5 Watt PV panel, (1) 256K Byte FLASH Card, steel shelter box, no sensors.
PAK-3	BaseStation Data Management Software with CardReader for 9300 Series Loggers	$ 800.00	
MODEM24	Internal PC modem for 9300CL CELLogger	$ 00.00	

Sensors

MODEL #		PRICE
40	WIND SPEED ANEMOMETER with rubber boot	75.00
40C	CALIBRATED ANEMOMETER with rubber boot	195.00
40H	HALL EFFECT ANEMOMETER with rubber boot	90.00
200P	NRG PRECISION WIND DIRECTION VANE with rubber boot	145.00
05103	R.M. YOUNG *Wind Monitor* PROP VANE	675.00
100S	NRG TEMPERATURE PROBE WITH RADIATION SHIELD	175.00
LI-200SA	LI-COR RADIATION SENSOR (PYRANOMETER)	290.00
BP15A	NRG BAROMETRIC PRESSURE SENSOR	250.00
RH-5	NRG HUMIDITY SENSOR	300.00
50202	R.M. YOUNG HEATED PRECIPITATION GAUGE	810.00
260-200	NOVALYNX TIPPING BUCKET RAIN GAUGE	350.00

Accessories

MODEL #		PRICE
DC64K	64K DATACHIP (for 9200 NRG Logger)	15.00
DC256K	256K DATACHIP (for 9200 NRG Logger)	40.00
256KB	256K BYTE FLASH CARD (for 9300 NRG Logger)	125.00
RB1	EXTRA RUBBER BOOTS for speed and direction sensors	3.50
B9VA-DPAK	5 YEAR BATTERY PACK	30.00
SBOX2-*	STEEL SHELTER BOX (9200) *Please specify tower diameter.	85.00
SBOX3-*	STEEL SHELTER BOX (9300) *Please specify tower diameter.	110.00
SMB1-*	SIDE MOUNT BOOM *Please specify tower diameter.	50.00
2C	2 CONDUCTOR CABLE	.30/FT
3C	3 CONDUCTOR CABLE	.30/FT
CAW08	BARE COPPER WIRE FOR LIGHTNING SPIKE *Please specify tower height.	.30/FT
GKIT/S	GROUNDING KIT WITH LIGHTNING SPIKE *Please specify tower diameter	50.00
WKIT	ELECTRIC (12 V) WINCH KIT	375.00
8120	POWER CURVE MONITOR	970.00

TOTAL P.03

NRG Systems

110 Commerce Street, Hinesburg, VT 05461 USA • (802) 482-2255 • FAX (802) 482-2272 • TELEX 650-313-4621 MCI UW

NRG TALLTOWER PRICE LIST (U.S.A. & CANADA)

October 1992

Part #	Price (U.S. Dollars)
30'TT	$ 385.00
30'TT-SS	485.00
30'TT-XP	605.00
50'TTC	710.00
50'TTC-SS	950.00
50'TTC-XP	1190.00
70'TTC	890.00
70'TTC-SS	1125.00
70'TTC-XP	1410.00
90'TTC	1280.00
90'TTC-SS	1650.00
90'TTC-SS-XP	2060.00
90'TTC-HD4.5	1690.00
90'TTC-HD4.5-SS	2100.00
90'TTC-HD4.5-XP	2630.00
110'TTC	2170.00
110'TTC-SS	2720.00
110'TTC-XP	3410.00
110'TTC-HD6	2820.00
110'TTC-HD6-SS	3540.00
110'TTC-HD6-XP	4420.00
140'TTC	2870.00
140'TTC-SS	3580.00
140'TTC-XP	4475.00
140'TTC-HD6	3740.00
140'TTC-HD6-SS	4675.00
140'TTC-HD6-XP	5200.00
165'TTC	4930.00
165'TTC-SS	5970.00
165'TTC-XP	7200.00

If ginpole not needed, subtract:

$150.00 (50', 70', 90')

$250.00 (90'HD4.5, 110', 140')

$375.00 (165')

TT= NRG TallTower

C= Complete with ginpole: ginpole not required for 30'TT. Please note that a single ginpole can be used for multiple tower installations. Please call NRG for details.

HD= Heavy Duty: 4.5" or 6" tower tube diameter

SS= Stainless steel guy wires and hardware (not tower tube)

XP= Extra Protection: epoxy coated tower tube with stainless steel guy wires & hardware for marine environments

**Actual installed height of tower is slightly less due to overlap of tube section joints.*

PRICES ARE F.O.B. HINESBURG, VT, U.S.A. AND SUBJECT TO CHANGE.

Consulting Engineers
1029 Solano Avenue
Albany, California 94706

510 525 0484
510 525 9410 FAX

Augustyn + Company

FAX TRANSMITTAL 2 page(s)

June 8, 1993

Karen Conover
R. Lynette & Associates
15042 N.E. 40th Street, Suite 206
Redmond, WA 98052

SUBJECT: Renewable Energy Resource Assessment and Development Program
Department of Business, Economic Development & Tourism, Hawaii

The field measurement equipment we propose to use for the 5 new sites is as follows:

1 - Ascension Technology RSS Unit - $5,700 each, f.o.b. Waltham, MA. Estimated shipping cost to ACI for calibration is $40, and from ACI to each site island is $75. This device consists of:

a. the RSP "Head Unit" containing a LI-COR 200SB pyranometer & the rotating band mechanism.
b. a Campbell CR10 datalogger, wiring panel, and DC112 modem mounted within a Campbell model weatherproof enclosure. The CR10 will be programmed to control the rotating shadow band mechanism and to perform necessary calculations to derive direct normal irradiance from total global horizontal and diffuse horizontal irradiance measurements.
c. a 12 volt rechargeable lead acid battery (to be mounted in the datalogger enclosure), charge controller, and photovoltaic panel used to provide power for the datalogger and rotating shadow band mechanism. All these will be provided with hardware to mount on a 1-1/4 inch pipe.

1 - Campbell model CM6 tripod assembly - $275 each, f.o.b. Logan UT. estimated shipping cost directly to the site island is $75. This device will be used as a base on which to mount the RSR unit if no easier and cheaper means of mounting is available (such as mounting on the parapet wall of a building's roof or other solid structure.

1 set - miscellaneous materials at $100.

So for each site, field equipment costs will be:

RSR:	$ 5,700
RSR shipping:	115
Tripod	275
Tripod shipping:	75
Misc materials	100
Total	$ 6,265..............times 5 sites = $ 31,325 which I rounded to $ 31,400.

I have attached a quotation from Ascension Technology to hold the $5,700 price for 5 units firm for 90 days. They didn't get the site names straight, but that shouldn't matter. Let me know if you need more.

Sincerely,

Jim Augustyn

Ascension Technology, Inc.
Proposal/Quotation
8 June 1993

To: Mr. James Augustyn
Augustyn + Company
Consulting Engineers
1029 Solano Avenue
Albany, CA 94706

Ref: Solar Resource Monitoring for Photovoltaic Generation Studies, dated May 1993.

Ascension Technology is pleased to provide this quotation for solar energy resource monitoring equipment to Augustyn + Company. We will ship five Ascension Technology Rotating Shadowband Pyranometer Systems to you at your Albany, CA address for your installation at locations in the Hawaiian Islands. At your request we will ship these directly to a receiving point(s) in Hawaii. Instrument specifications and their operation are described in the referenced document, a copy of which I believe you have.

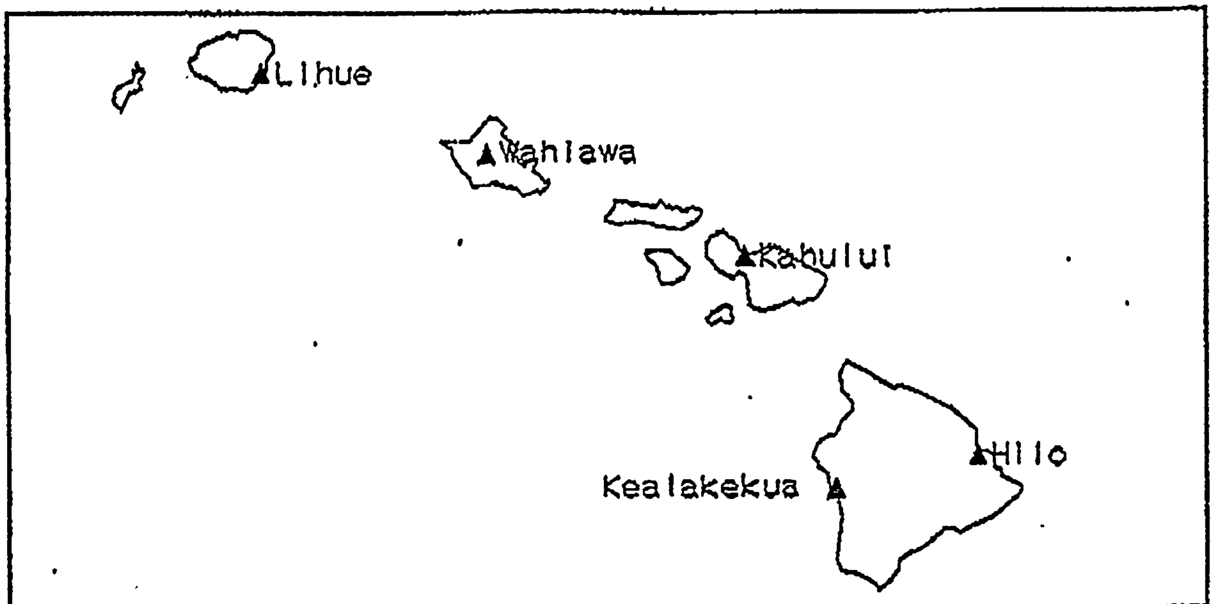


Figure 1 Possibly Solar Monitoring Locations

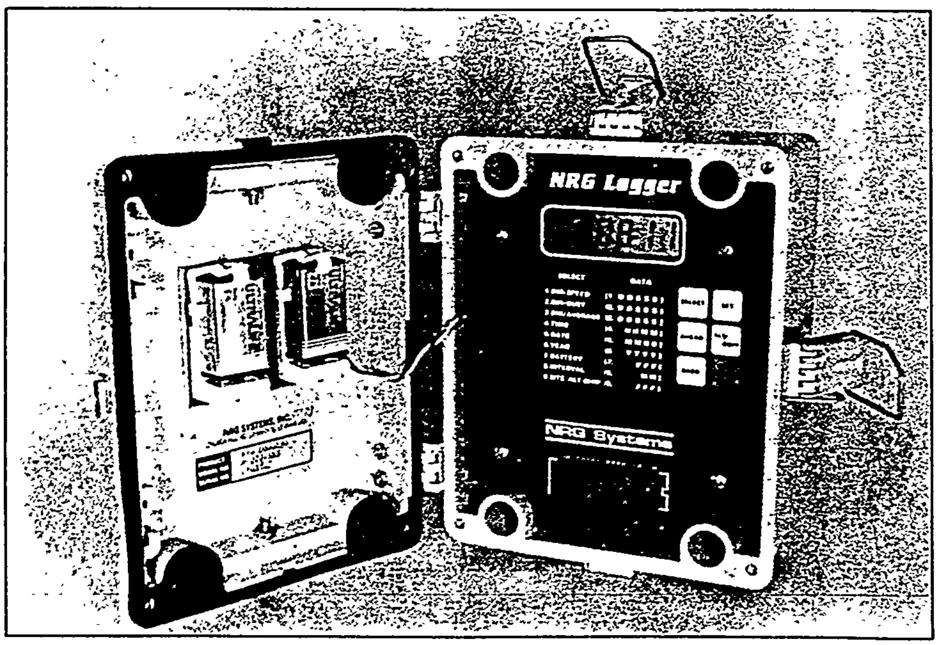
Five (5) Rotating Shadowband Pyranometers @ $5,700.	$28,500.00
Total:	**$28,500.00**

Terms: FOB Waltham, MA, Net 30 days

NRG Systems

LOGGER 9000 SERIES

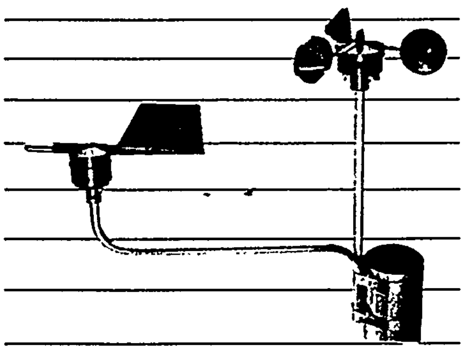
SERIAL DATA LOGGER



THE LOGGER 9000 SERIES real-time serial data logger was designed to meet the needs of our customers in the fields of wind energy, air quality monitoring and meteorology. The Logger Series has proven successful in global applications, incorporating the most-requested functions at a realistic price. The system is simple to operate, maintains high reliability, provides easily transferred data to the user's own PC-based system and only requires standard, locally available 9 volt batteries. Data and system variables may be reviewed manually using the keypad and LCD display, or read automatically from the removable data chip. Combined with the NRG EEREADER data chip hardware, associated DATALOG software for PCs and the NRG TallTower™ instrumentation mast, the Logger 9000 series offers a total data gathering system, all from one manufacturer.

NRG Systems

1955 Church Hill Road ■ Charlotte, VT 05445 USA ■ (802) 425-3468 ■ FAX 802-425-3712 ■ Telex 650 313 4621 MCI UW



NRG Systems: A Respected Name in the Wind Power Industry.

NRG Systems specializes in wind instrumentation and related equipment. Services include: complete siting studies, custom electronic, electrical and mechanical design and manufacturing.

NRG Systems' wind direction sensors, instruments and TallTowers™ are in use on all major wind farms and many monitoring sites in the United States and around the globe, including Antarctica, Australia, Africa, the Carribean, Egypt, Greece, India, Israel and South America. The number of installations continues to grow as NRG's expertise and complete packages provide simple installation, ensured compatability and value.

NRG's use of the latest CAD design tools, state of the art circuit technology and proprietary equipment indicate the depth of our commitment to quality and innovation.

Configurations and Options

The LOGGER 9000 SERIES is offered as the #9000 (single speed/single direction and the #9000-2 (dual speed/single direction). These two versions deliver flexible monitoring, providing the ability to measure wind shear in complex terrain. Both versions of the LOGGER 9000 come complete with sensors, cable, sensor mounts, batteries, data chip and instruction manual.

The sensors are widely used in wind studies and turbine control. The Maximum #40 anemometer continues to be a consistent performer. The NRG 200P direction vane was developed to stand up to the rigors of harsh wind energy sites. The potentiometer is rugged and sealed with a teflon dust barrier. The shielded sensor cable is terminated with lugs; sensor mounts are anodized aluminum aircraft tubing. 9-volt lithium batteries are now supplied as standard equipment.

Optional equipment and accessories available include: steel shelter box, mounting hardware, extra sensor cable, R.M. Young wind sensors for air quality measurements and the popular NRG TallTower™ instrumentation masts.

EEREADER and DATALOG Software

The EEREADER module includes a plug-in short card for PCs and compatibles with a cable and EEPROM data chip socket holder. The hardware, when coupled with the datalog software, allows the operator to read data chips, store data to disk files, print data, print reports and erase data chips for the next use.

Data is available in ASCII format with date and time stamps for use by the customer's own software for detailed analysis. DATALOG software can be used to generate reports. Printouts include: sequential windspeed/direction/standard deviation report; windspeed/direction and diurnal distributions.

The sequential printout clearly shows the wind data at any time during the recording period, with date and time indicated. A unique velocity/direction/turbulence intensity report provides a wealth of information about the site in one printout. The diurnal distribution gives velocity, direction and turbulence intensity summaries for each hour of the day for the period of data recording.

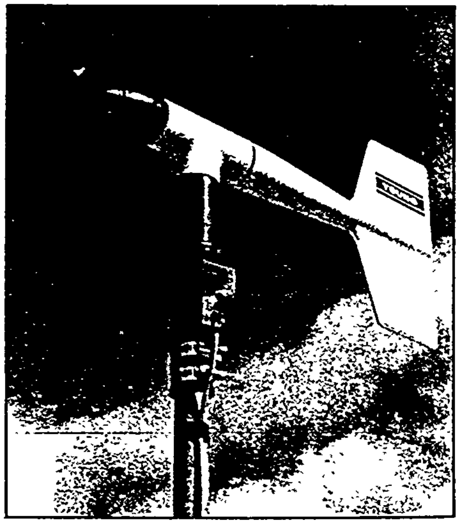
Far Left: *The Logger 9000 comes complete with sensors, cable and sensor mounts.*
Left: *Reading the data chip with a PC.*

Left: *A complete mountain top logging station featuring the TallTower™ from NRG.*

NRG Systems

FEATURES:

- Ultra-low power consumption—operates on two 9-volt lithium batteries for over 12 months. Readily available standard 9-volt batteries may be used. A battery voltmeter is built in. Two batteries allow continuous operation when changing batteries, operation of the logger is never interrupted.
- Redundant data memory—data stored on internal RAM in addition to the EEPROM data chip. Copy function may be used to back-up data chip; prevents lost data.
- Four user-selectable averaging periods—5, 10, 30 and 60 minute periods for versatile operation.
- All operating parameters (time, date, serial number, model number, site, battery voltage, etc.) are stored on the data chip for review on a PC.
- Real-time serial data is stored in a removable data chip for offsite transfer to an IBM PC or compatible computer for data reduction.
- Easy to operate—can be set up in your office or lab and activated on site. Data changes are simple and quick; push one key, pull data chip, insert new data chip, push the key again and you're finished. A 6 key data entry pad and a 6 digit LCD display makes setup straightforward.
- Initial parameters remain in memory. No need to reset parameters after changing data chips. Greatly reduces the chance of data retrieval error. Parameters may be changed at any time if desired.
- Data chip can be changed at ANY TIME without losing data. The logger continuously records data irrespective of whether the EEPROM data chip is in place.
- Meets or exceeds all siting standards of the American Wind Energy Association.
- Very reliable operation, low integrated circuit count reduces complexity, cost. Leading edge technology provides consistent performance. All ICs and internal connections soldered in and coated with a military spec. moisture barrier.
- Turbulence intensity (standard deviation/mean velocity) is calculated based on all 1 second samples over the averaging interval. Turbulence intensity is a standard indicator of turbulence. Wind turbine's power production, mechanical stress levels and life may be affected by turbulence.



Right: *The optional R.M. Young "Wind Monitor."*

NRG LOGGER 9000 SERIES

MECHANICAL SPECIFICATIONS:

Enclosure:
NEMA type 4, 4x & 13 IEC: IP65 weatherproof fiberglass with stainless steel & polyester hardware. Hasp for padlock and quick release latches.

Size:
17cm high × 20cm wide × 14cm deep (6.5in. × 8in. × 5.5in.)

Weight:
2.3kg (5lbs.)

Shipping Weight:
4kg (9lbs.)

SYSTEM OPERATIONS:

Time Base and Real-Time Clock:
Accuracy: +/−3 minutes per month.
Software Programmable clock via keypad.
Automatic leap year correction.

Power Requirements:
Battery Voltage: 9 volt nominal, 5.6 volt minimum.
Operating Current: Less than 200 uA (0.2 ma) average.

Battery Life:
Over 1 year with 9 volt lithium batteries; standard alkaline batteries may be used.

Data Storage:
Permanent Removable Storage: 2864 EEPROM (commercial temperature rated) in protective data chip carrier.
Maximum Storage: 85 days of hourly data (42 days on 9000-2).
Fixed On-Board Storage: CMOS SRAM redundant memory.

Data Sampling and Display:
6 digit, 13mm (0.5in.) LCD
Wind Speed: 1 second update, count integrated.
Resolution: +/− 1 MPH (0.45 m/s)
Range: 0–128 MPH (0–57.6 m/s)
Accuracy: +1, −0 MPH (+0.45, −0 m/s)
Wind Direction: 2 second update, software compensated for vane deadband.
Resolution: approx. 1 deg (internal A/D converter); Sixteen points of compass (22.5 degrees) displayed.
Accuracy: +/− 4 degrees

Sensors:
*On 9000-2, model: two anemometers are used.
All low pass filtered and electrostatic discharge protected.
Wind Speed: Interfaces directly to Maximum #40, or R.M. Young Sentry™AC anemometer (60hz = 102 MPH (45.9m/s).
Wind Direction: Interfaces directly to NRG #200P or R.M. Young Sentry™potentiometer type wind vane (resistance = 10k).

FUNCTIONS:

Peak Wind Gust:
Peak wind gust updated every second, Peak Gust, direction of gust, time and date recorded.
Range: 0–255 MPH (0–116 m/s)
Resolution: 1 MPH (0.45 m/s)
Accuracy: +1, −0 MPH (+0.45, −0 m/s)

Average Windspeed/ Prevailing Wind Direction:
Average speed and most frequent direction calculated for each time interval (5, 10, 30 or 60 minutes).
Range: 0–127.9 MPH (0–58.1 m/s), 0–15 direction sectors.
Resolution: 0.1 MPH (0.05 m/s), 1 direction sector.
Accuracy: +/− .5 direction sectors.

Windspeed Standard Deviation (for turbulence intensity):
*On 9000-2 models: the standard deviation is calculated for only one anemometer.
True standard deviation with 1 second intervals.
Resolution: 0.1 MPH (0.05 m/s)
Accuracy: +/− 0.1 MPH (0.05 m/s)

Battery Voltmeter:
Battery voltage updated every 2 seconds.
Range: 5.5 to 9.95 volts
Resolution: .05 volts

Averaging Interval:
Dip switch selected.
Range: 5, 10, 30 and 60 minutes

Ordering Information:
Logger (single speed/direction)—complete............Cat. No. 9000
Logger (dual speed/single direction)—complete........Cat. No. 9000-2

SPECIFICATIONS MAY CHANGE WITHOUT NOTICE

LOGGER 9000 SERIES

SERIAL DATA LOGGER

NRG Systems

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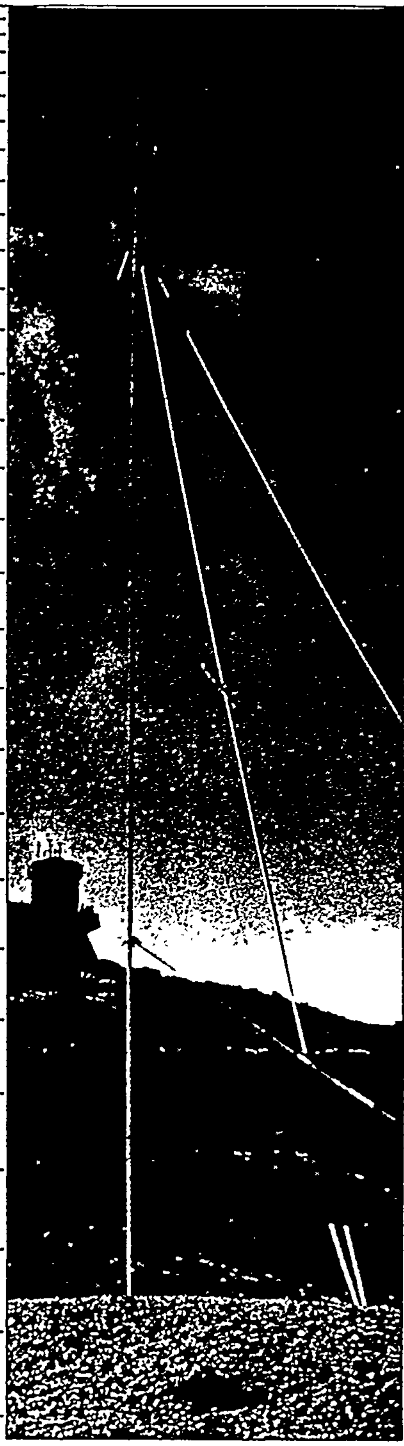

THE TALL TOWER

MAST SYSTEM

THE NRG TALLTOWER™ is a highly versatile, easy to erect, tilt-up tower suitable for many instrumentation applications. NRG TallTowers™ have become an industry standard for wind resource assessment; more than 500 units have been sold for use as meteorological masts in wind farm and remote site installations. New TallTower™ models are constantly being developed, and existing models continuously updated to incorporate improvements. (For example, NRG now offers special heavy service tower systems in heights up to 110′ for use in extreme conditions such as rime ice accumulation.) We take great pride in the quality, durability and innovation you'll find in every NRG product. The TallTower™ line and our custom tower services perfectly complement our selection of fine instruments. Available in many standard heights from 30′ to 140′ (10 to 40 meters).

NRG | THE TALLTOWER™

NRG Systems

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Take the guesswork out of measuring wind speeds at turbine hub height.

There's only one truly accurate way to estimate a wind turbine's energy output: measure the wind speed at the turbine's hub height. Extrapolation from measurements made from shorter towers is, at best, an educated guess; if you're dealing with local obstructions or varying terrain, it may become nearly useless.

NRG's TallTower™ wind measurement mast systems are available in many standard heights from 30′ to 140′. Wind power professionals can now monitor wind speeds at heights approaching 140′...accurately, economically.

If you're testing for air quality, you shouldn't have to worry about the quality of your equipment, too.

As the need for the monitoring of both local and larger areas for scientific uses increases, the need for inexpensive, portable, easily erected masts also increases. NRG has supplied many 10M masts for this purpose and will continue to fill the growing demand for air quality equipment.

We can supply many types of mounting hardware for your sensors, or adapt your existing equipment for more dependable operation.

If you're looking for high-quality, low-cost monitoring equipment, look to NRG Systems for equipment you can depend on...for years to come.

Antennas go up safer, easier and economically.

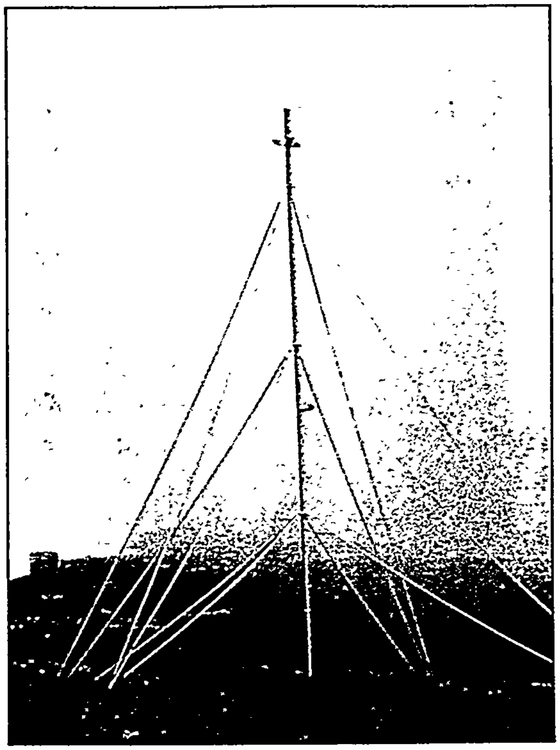
The TallTower's™ light weight and tubular construction make the mast ideal for installations in confined spaces. The tower is easily raised and lowered to provide safe access; antenna mounts are easily attached and wires may be run internally, affording protection from the elements. NRG quality and an installation cost far less than that of comparable guyed towers have made the TallTower™ *the* choice for antenna installations.

Now you won't have to cut costs at the expense of accuracy, economy or safety.

Before the TallTower™ system's introduction, erecting a mast of 10′ or more was costly, time-consuming and labor-intensive. In the past, excavation for anchor holes, poured concrete for anchor pads and base footings, and the large crews required all contributed to making mast erections expensive—and often dangerous. With NRG's Talltower,™ towers are installed safely, quickly and economically. When greater efficiency is at stake, an NRG TallTower™ is an investment that really makes sense.

Screw-in earth anchors are easily installed...no concrete is required.

Tilt-up installation means no climbing ...all work is done at ground level.



TESTED ATOP MOUNT WASHINGTON!

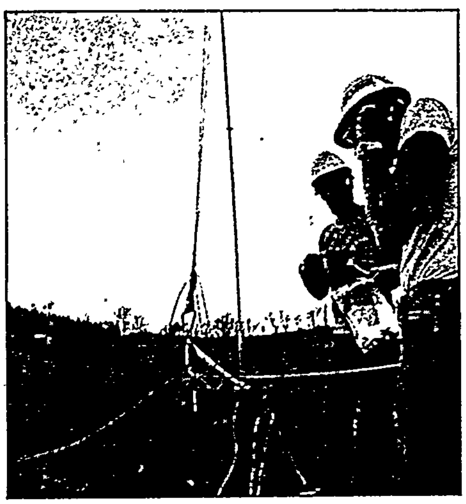
Shown at left is a test model of the 70' TallTower™ undergoing field testing at the summit of Mount Washington, N.H. in the fall of 1983. Despite winds exceeding hurricane force and rime ice build-up (visible on the guy wires in this photo), the TallTower™ stood its ground. NRG supplies a full line of special heavy service mast systems for such extreme conditions.

NRG Systems

The professional tower that takes the headaches out of installation.

Despite all its professional-level qualities, the TallTower™ system from NRG features the most easily-erected masts available today. Two people can handle the complete installation, with the aid of only a small winch or hoist and a minimum of common hand tools. Mast sections slide together without the use of clamps or bolts, and the unique hinged base plate allows assembly on the ground, permitting both the tower and ginpole to pivot into erected position. (The hoist isn't included, but any lifting device with a working load of 2000 lbs. is adequate.) The screw-in earth anchors are suitable for use in nearly any type of soil. Arrowhead anchors and drive rods available for hard or rocky soils. Also available are 12 VDC electric winches for erection.

A crew of two can handle most installations...only simple tools are required.



Simple guywire attachment method eliminates hardware, speeds assembly.

NRG

THE TALLTOWER™

SPECIFICATIONS:

GENERAL:

- Tubular tower, guyed in 4 directions, tilt-up from ground level
- Galvanized steel tower tubes, 3 m (10 ft) sections
- Galvanized aircraft cable guywires
- Guywires are pre-cut, rolled on spools and swaged to guy rings
- Maximum design windspeed: 55 m/s (120 mph) [13 mm (0.5 in) ice max. per EIA spec.]
- Baseplate, guy rings and hardware hot-dipped galvanized
- Detachable gin-pole for erecting
- Screw-in earth anchors for "normal" soils
- Complete kit, ready to install—with gin-pole, anchors, baseplate, guywires, hardware and instructions
- Special TallTowers™ available for severe environments
- Non-standard heights also available
- Arrowhead and rock anchors are optional

10 to 20 meter, 30′ to 70′ TallTowers™:

- Tower tubes of 73 mm (2.88 in) diameter, 15 gauge
- Guywire is 3.2 mm (0.125 in) diameter
- 20 m, 50′ and 70′ with 6 m (20 ft) ginpole
- Screw-in anchors with 10 cm (4 in) plate, 107 cm (42 in) long
- Erected heights: 10 m - 10 meters, 20 m - 20 meters, 30′ - 29 feet, 50′ - 48.5 feet, 70′ - 68 feet

30 meter, 90′ and 110′ TallTowers™:

- Tower tube of 89 mm (3.5 in) diameter, 15 gauge
- Guywire is 3.2 mm (0.125 in) diameter
- All with 7.6 m (25 ft) ginpole
- Screw-in anchors with 15 cm (6 in) plate, 122 cm (48 in) long
- Erected heights: 30 m - 30 meters, 90′ - 87 feet, 110′ - 106 feet

40 meter and 140′ TallTowers™:

- Tower tube of 114 mm (4.5 in) diameter, 14 gauge
- Guywire is 4.8 mm (0.188 in) diameter
- All with 9 m (30 ft) ginpole
- Screw-in anchors with 15 cm (6 in) plate, 122 cm (48 in) long
- Erected heights: 40 m - 40 meters, 140′ - 132 feet

Ordering Information:

30′ TallTower™—complete	Cat. No. 30TT	51 kg	(112 lbs)
50′ TallTower™—complete	50TT	110 kg	(242 lbs)
70′ TallTower™—complete	70TT	139 kg	(306 lbs)
90′ TallTower™—complete	90TT	200 kg	(441 lbs)
110′ TallTower™—complete	110TT	244 kg	(536 lbs)
140′ TallTower™—complete	140TT	471 kg	(1036 lbs)
10 meter TallTower™—complete	10MTT	54 kg	(119 lbs)
20 meter TallTower™—complete	20MTT	139 kg	(306 lbs)
30 meter TallTower™—complete	30MTT	240 kg	(528 lbs)
40 meter TallTower™—complete	40MTT	471 kg	(1036 lbs)

SPECIFICATIONS MAY CHANGE WITHOUT NOTICE

THE TALL TOWER

MAST SYSTEM

NRG Systems

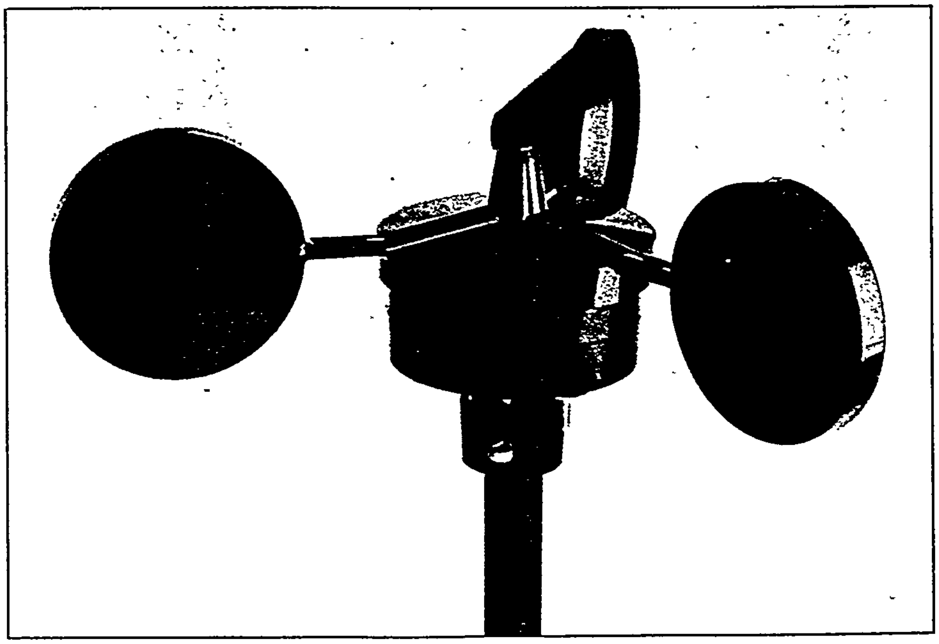
1955 Church Hill Road ■ Charlotte, VT 05445 USA ■ (802) 425-3468 ■ FAX 802-425-3712 ■ Telex 650 313 4621 MCI UW

NRG TYPE 40 MAXIMUM ANEMOMETER

NRG Systems

TYPE 40 MAXIMUM ANEMOMETER

THE MAXIMUM TYPE 40 ANEMOMETER has proven to be rugged, reliable and highly accurate. Over 50,000 units are now in use in wind tunnels, on mountain-tops and in thousands of household, wind energy and institutional installations. Maximum cup anemometers have recorded wind to 97 m/s (214 mph). Their low moment of inertia and unique bearings permit very rapid response to gusts and lulls. The black Lexan cups (virtually shatterproof) have thermal properties which resist and shed icing far more effectively than metal assemblies. Because of their output linearity, these sensors are ideal for use with various data retrieval systems and controllers. The unique bearing system ensures that wind-blown dirt and moisture will not destroy the bearings or degrade performance. The #40 has three conical cups molded in one continuous piece. Cup rotation induces a AC sinewave voltage in a single coil by a four pole magnet. Two sine wave cycles are produced for each revolution of the cups with the frequency directly proportional to windspeed. The unbeatable combination of high accuracy, stable bearings, simple yet rugged construction and very low cost make the Type #40 the first choice for professionals in all fields.



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NRG

TYPE 40 MAXIMUM ANEMOMETER

APPLICATIONS

- Anemometer for wind resource assessment instrumentation
- Research measurements in environmental studies
- Engineering studies on wind effects on bridges, skyscrapers
- Sensing wind speeds at sporting events (i.e. Olympics)

FEATURES:

- Very simple, elegantly engineered construction
- Dirt and water resistant, modified Teflon bearing system
- All corrosion resistant materials
- All 3 cups molded in one piece for repeatable performance
- Frequency output for ease of filtering and long cable runs
- Professional qualities at a mimimum price

SPECIFICATIONS:

Mechanical:

3 cups of conical cross-section, 51 mm (2 in) diameter
190 mm (7.5 in) swept diameter of rotor
51 mm (3.2 in) overall assembly height
Moment of inertia of rotor assembly = 68×10^{-6}S–ft^2
Mounting—(using a cotter pin) on a 13 mm (0.50 in) diameter mast with a #35 hole 11 mm (.35 in) from the top.

Materials: Cups—one piece injection-molded black polycarbonate (Lexan)
Body—housing is black ABS plastic.
Shaft—beryllium copper—fully hardened
Bearing—modified Teflon, self-lubricating. Rated Pv factor of 20,000 (at 15 mph, Pv is approx. 500; at 100 mph PV is approx. 2,000.) Upper bearing is centered in the plane of cup thrust for optimal loading.
Permanent magnet—Indox 1, 25 mm (1 in) dia., 13 mm (0.5 in) long, 4 poles

Threshold: Starting threshold—1.1 m/s (2.5 mph)
Cup distance constant (63% recovery)—3.0 m (10 ft)

Environmental: Operating temperature −55°C to 60°C (−67 to 150 F)
Operating humidity range 0 to 100% RH

Weight: 0.1 kg (0.2 lbs)
Shipping Weight: 0.5 kg (1 lb)

Electrical:

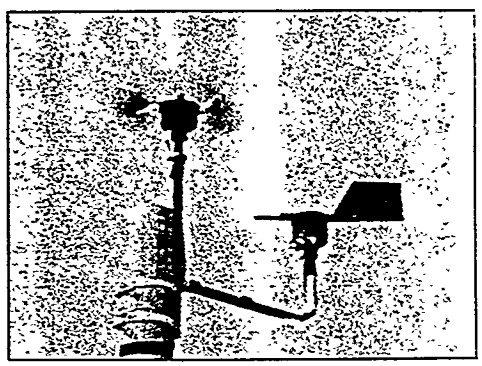
Single coil, bobbin wound, 4100 turns of #41 wire
Voltage is a sine wave with frequency changing linearity with wind speed—
60 Hz = 102 mph
Voltage is 2.0 VAC at 60 cycles

Ordering Information:

#40 Anemometer........Cat. No. 40

SPECIFICATIONS MAY CHANGE WITHOUT NOTICE

TYPE
40
MAXIMUM
ANEMOMETER



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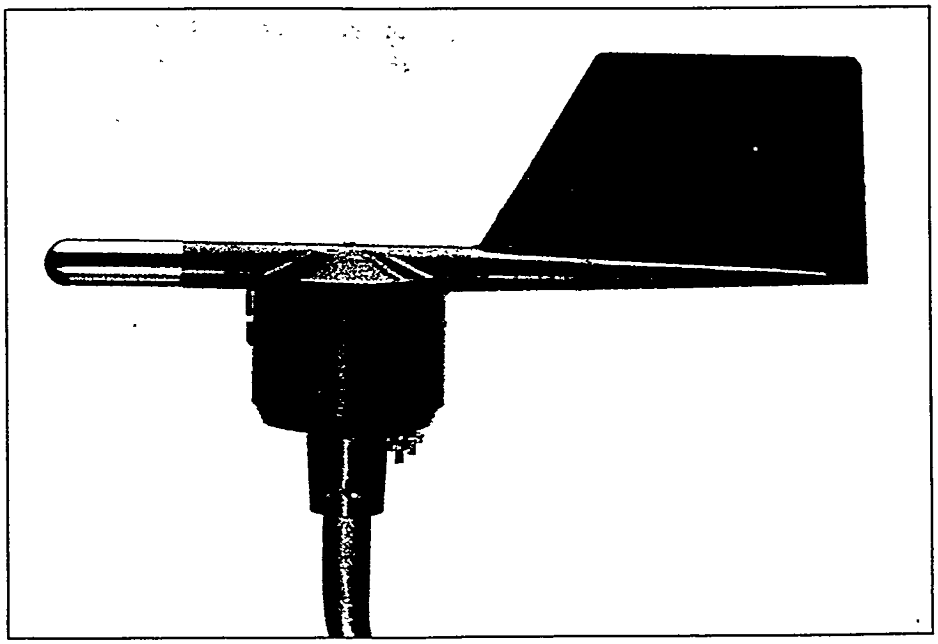
200 SERIES WIND DIRECTION VANE NRG

THE 200 SERIES WIND DIRECTION VANE is a professional quality wind sensor, designed for and proven effective in some of the world's largest wind power plants. Its many qualities also make the 200 Series ideal for use in many other areas, including applications in environmental testing and meteorology. Although moderately priced, these sensors offer a level of quality and reliability often found only at a very high premium. The thermoplastic and stainless steel components resist corrosion, and contribute to a high strength-to-weight ratio. As with all NRG Systems products, the 200 Series Vane is elegantly engineered, employing a minimum number of parts while maximizing functional performance. The vane is directly connected to a precision conductive plastic potentiometer located in the main body. An analog voltage output directly proportional to the wind direction is produced when a constant DC excitation voltage is applied to the potentiometer.

NRG Systems

200 SERIES
WIND VANE
WIND DIRECTION SENSOR



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NRG

200 SERIES WIND DIRECTION VANE

200
SERIES
WIND VANE

APPLICATIONS
- Wind direction sensor for wind data loggers
- Yaw control on wind turbines
- Environmental monitoring instrumentation

FEATURES:
- Simple mechanical construction
- Long life, professional quality potentiometer
- No slip rings or brushes result in high reliability & low cost
- Corrosion resistant materials
- Multiple mechanical and contact seals
- Completely balanced sensor vane
- No setscrews to vibrate loose
- Very stable and smooth response to wind changes
- Fully balanced sensor vane

SPECIFICATIONS:
Mechanical:

Range: Direction—360° mechanical, continuous rotation

Sensitivity: approx. 1.4 m/s (3 mph)

Materials: Direction vane and housing—black u.v. stabilized injection molded polycarbonate
Balance weight—stainless steel
Terminals—three #4-40 solid brass studs with nuts
Potentiometer—stainless steel shaft in two shielded precision grade, stainless steel ball bearings, conductive plastic potentiometer element mounted in a machined aluminum housing.
Hardware—all of stainless steel construction

Dimensions: Overall length—21 cm (8.3 in)
Swept diameter—27 cm (10.5 in)
Overall height—12 cm (4.3 in)
Vane size—6 cm high × 10 cm long (2.3 in × 3.8 in)
Main housing diameter—5 cm (2 in)
Mounting—13 mm (0.5 in) diameter mast

Weight: 0.1 kg (0.25 lb.)

Shipping Weight: 0.5 kg (1 lb.)

Electrical:

Range: Direction—340° electrical (20° open)-#200
352° electrical (8° open)-#200 P

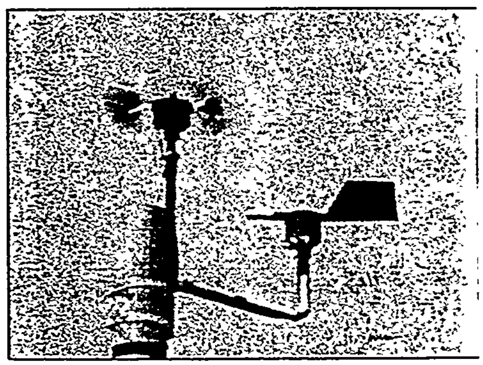
Signal: Analog DC voltage from conductive plastic potentiometer resistance 1K-#200, 10K-#200P, linearity 1.0%, life expectancy of 50 million revolutions (4-6 years normal operation).

Power Requirements: Regulated potentiometer excitation of 5 to 15 VDC.

Ordering Information:

Wind direction vane—1K ....Cat. No. 200
Precision wind direction vane—10K........Cat. No. 200P

SPECIFICATIONS MAY CHANGE WITHOUT NOTICE



NRG Systems

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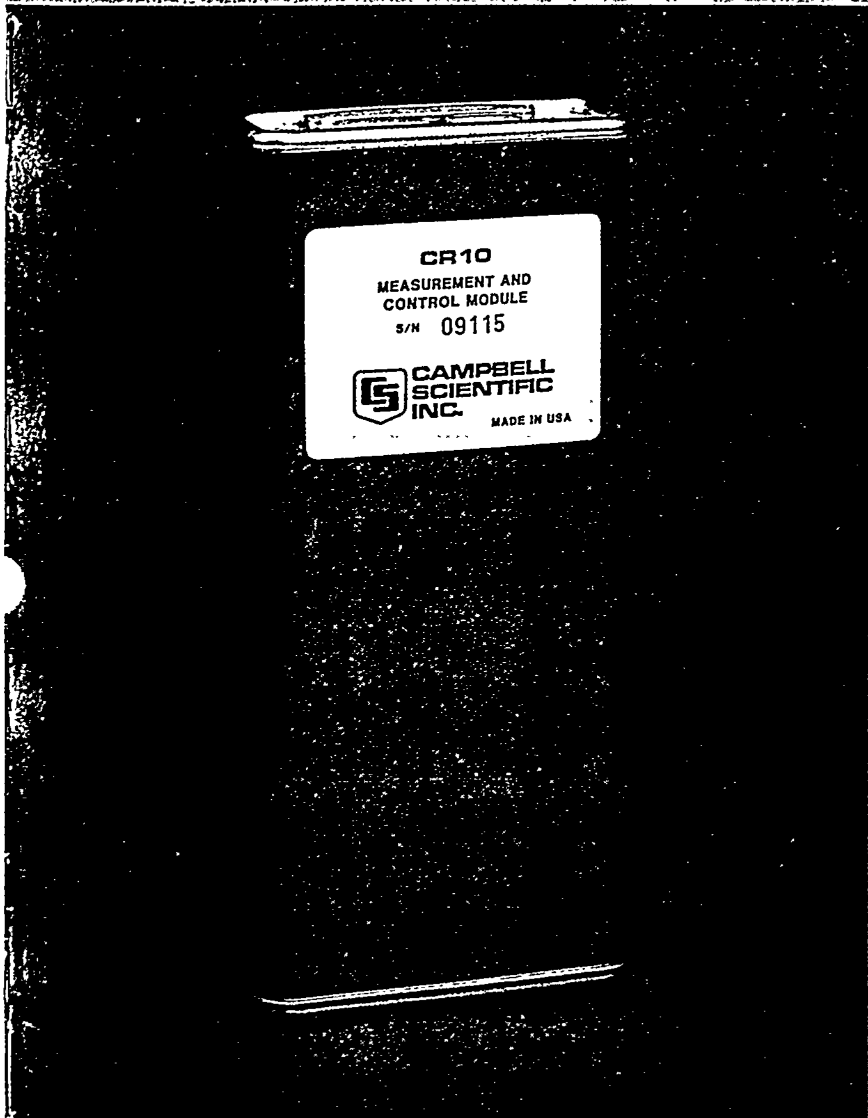
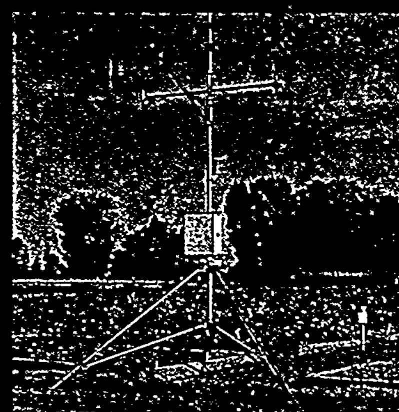
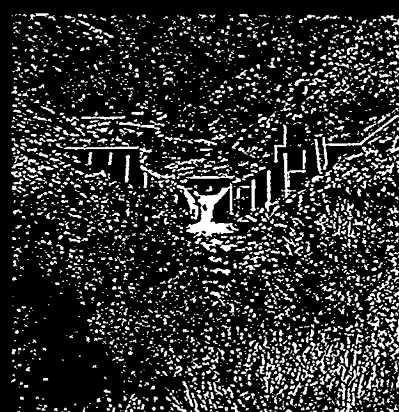
CR10 Measurement & Control System





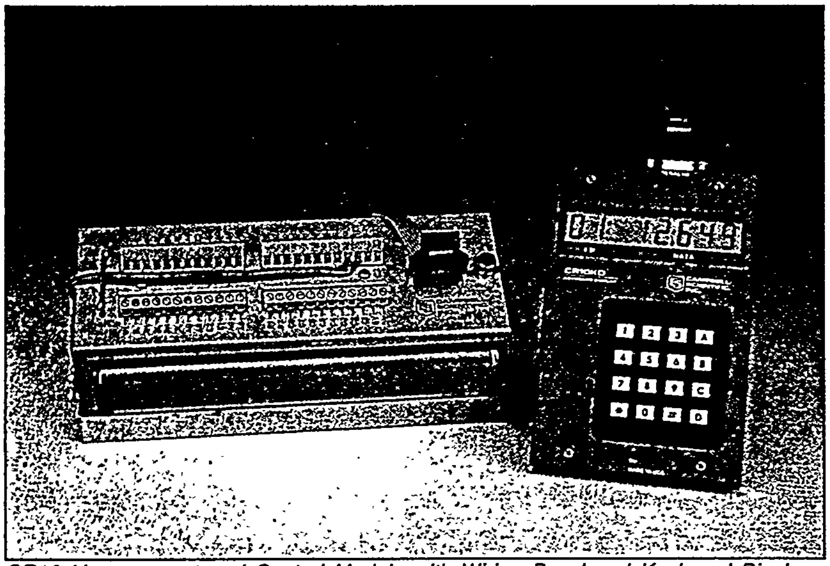


CAMPBELL SCIENTIFIC, INC.

CR10 Measurement and Control System

A Rugged, Operational Instrument with Research Grade Performance

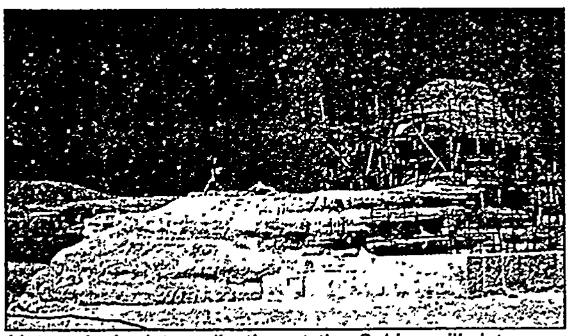
The CR10 combines a micro-computer, clock, multimeter, calibrator, scanner, timer, frequency counter, and controller in a compact, sealed, stainless steel package.



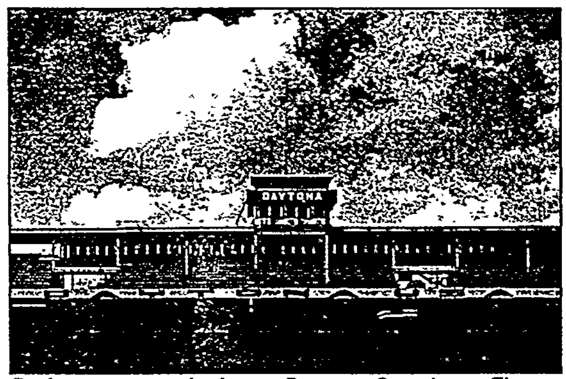
CR10 Measurement and Control Module with Wiring Panel and Keyboard Display.

TABLE OF CONTENTS

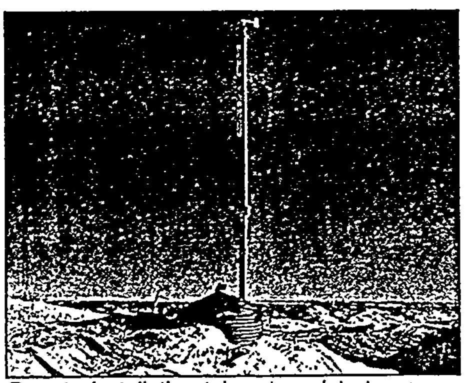
Campbell Scientific data acquisition systems deliver accurate, reliable measurement and control capability, even in extreme environments. Our systems have collected data on every continent and in space.



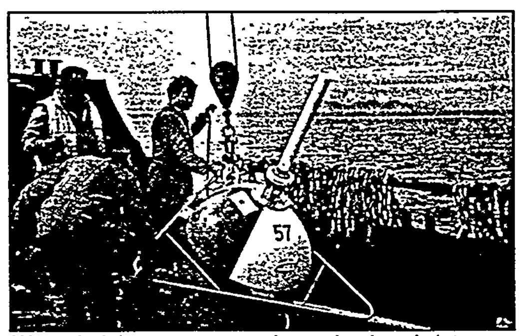
Meteorologic data collection at the Sphinx will determine an appropriate course for preservation and restoration. Photo courtesy The Getty Conservation Institute.



Performance monitoring at Daytona Speedway, FL.



Remote installation telemeters data to an adjacent valley (Bear River Range, Wasatch Mountains, UT).



Wave height spectra are determined and data telemetered via satellite (Bering Sea, AK). Photo courtesy Brown & Caldwell.

Cover Photos: At left: CR10 Measurement and Control Module. From top right: (INDUSTRY) Turbine performance and hook load testing, photo courtesy Aerospatiale Helicopters, Inc.; (RESEARCH) NASA CELSS Research Lab, Utah State University, Logan, UT; (AGRICULTURE) Agriculture Research Plots. Logan, UT; (HYDROLOGY) Weir in Reynolds Creek Drainage, southeast of Boise, ID.

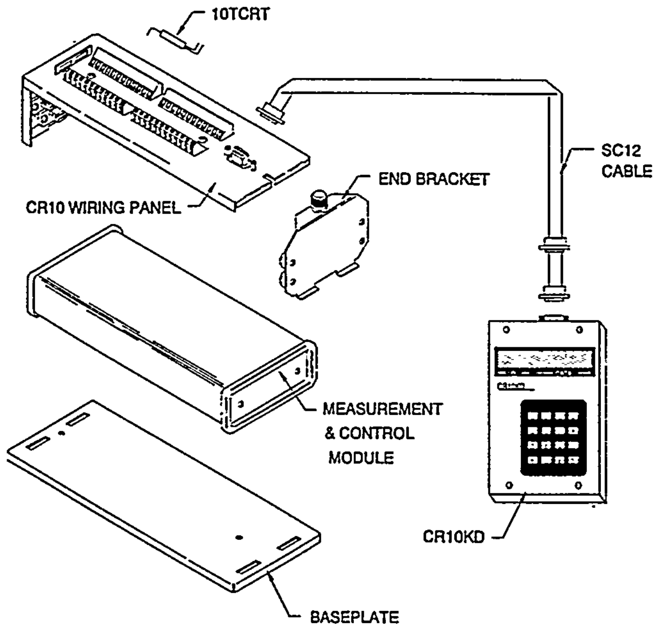
System Description

The primary components of the CR10 are the Measurement and Control Module and the detachable Wiring Panel. The CR10 Keyboard Display is recommended for on-site communication, station setup and trouble shooting, but may be replaced by a computer where environmental conditions allow.

12 Analog Inputs - (single-ended channels, each pair differential*) Five software selectable input voltage ranges. Resolution is 0.33 µV on the 2.5 mV range (0.006°C on type E thermocouple). An AM416 multiplexer provides additional inputs. Vibrating wire sensors may be read with any analog input.

8 Digital Inputs/Outputs for output control, sensing status, or reading SDM peripherals or SDI-12 sensors.

9-Pin Serial I/O Port for connection of data storage, retrieval and telecommunications peripherals.



2 Pulse Counting Channels are software selectable for switch closures, high frequency pulses or low level AC measurement.

3 Switched Excitation Channels for precision excitation of sensors or short-term actuation of external devices. Excitation is programmable over a ±2500 mV range.

Power and Ground Connections for 12 VDC external batteries or peripherals.

CR10 MEASUREMENT AND CONTROL MODULE

Protected in a sealed, rugged, stainless steel canister, the programmable module provides sensor measurement, timekeeping, communication, data reduction, data/program storage and control functions. A multitasking operating system allows simultaneous communication and measurement functions. Operating temperature range is -25° to +50°C, standard; -55° to +85°C, on request.

The standard CR10 instruction set includes 30 measurement instructions, 43 processing/math instructions, and 15 program control instructions. Optional instructions are available for specialized measurement or processing capabilities.

The CR10's standard memory configuration allows storage of 29,900 data points in two Final Storage areas. The SM192 and SM716 Storage Modules provide additional on-site data storage, if required.

The Measurement and Control Module interfaces with the Wiring Panel via two D-style connectors. The CR10's electronics are RF shielded and glitch protected by the sealed, stainless steel packaging. A "watchdog" hardware reset function restores normal microprocessor function if lost due to an input transient or intermittent component failure.

WIRING PANEL

The stainless steel Wiring Panel consists of a top panel and end bracket. The top panel includes screw terminals for sensor connections and a 9-pin serial I/O port; the end bracket attaches the Wiring Panel to the Control Module and to an enclosure-mounted or free-standing baseplate. The Control Module easily disconnects from the Wiring Panel for quick field replacement thus avoiding the need to rewire sensors. All wiring panel connections are protected with spark gaps or transzorbs.

CR10KD KEYBOARD/DISPLAY

The portable CR10KD is used to program the CR10, manually initiate data transfer, and display sensor readings, stored values, or flag/port status. One CR10KD may be carried from station to station in a CR10 network. The CR10KD features an 8-character LCD and a 16-character keyboard. Operating temperature range is -25° to +50°C. The CR10KD is powered by the CR10's power supply.

10TCRT THERMOCOUPLE REFERENCE

The 10TCRT thermistor provides a temperature reference in thermocouple applications. It requires one single-ended analog input. Overall accuracy is typically better than ±0.2°C over the range -33° to +48°C.

PERIPHERALS

The CR10 must be powered by a 9.6 to 16 VDC supply and housed in a weather resistant enclosure (page 8). Measurement, control, and data storage/transfer peripherals are optional depending upon the user's application (pages 4 and 5).

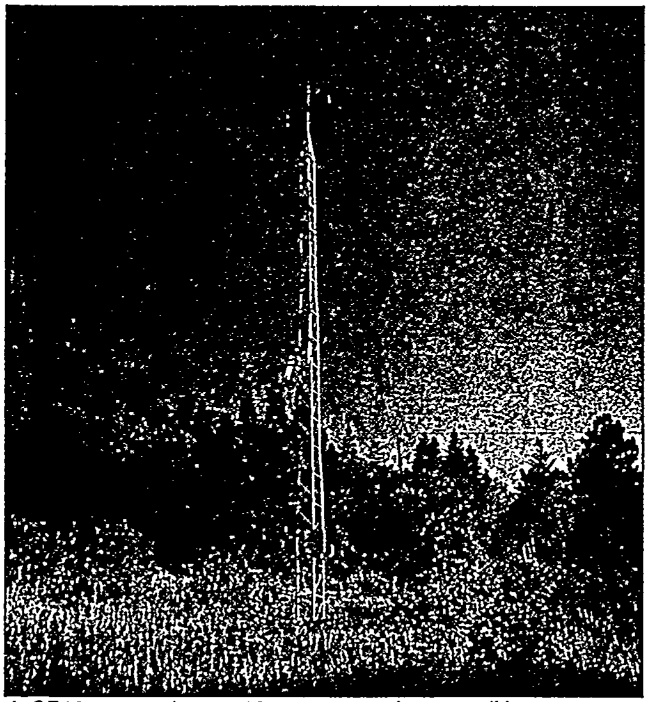
*A differential measurement measures the difference in voltage between two inputs. A single-ended measurement measures the input with respect to ground. All inputs must be within the ±2.5 V common mode range of the CR10.

Applications

The CR10's combination of measurement precision, flexibility, long-term reliability and economical price has resulted in its widespread use in scientific, commercial and industrial applications. Popular applications are discussed below.

METEOROLOGY

The CR10 is designed for long-term climatological monitoring, meteorological research, and routine weather measurement applications. Standard CR10 outputs include wind vector averaging, sigma theta, vapor pressure from wet/dry bulb temperatures, saturation vapor pressure, and histograms.



A CR10 mounted on a 10m tower monitors conditions at a proposed site for the 1998 Winter Olympics (Summit County, UT).

Typical meteorologic measurements:

- WIND SPEED is measured with voltage, photo-chopped, switch closure, or magnetic pulse type anemometers. Expansion peripherals allow wind profile studies.
- WIND DIRECTION is measured by a precision potentiometer wind vane.
- SOLAR RADIATION is measured with a silicon cell or thermopile pyranometer.
- TEMPERATURE sensors include thermistors, thermocouples, RTD's, or silicon types.
- RELATIVE HUMIDITY is measured with wet/dry bulb psychrometers, AC resistive sensors, strain gage or capacitive sensors. Capacitive probes include signal conditioning.
- DEWPOINT is calculated from temperature and relative humidity data or measured by cooled mirror or lithium chloride sensors. Dew point sensors require external power.
- PRECIPITATION data is provided by a tipping bucket switch closure rain gage or a weighing gage.
- EVAPORATION is measured with standard pans or lysimeters fitted with a potentiometer or strain gage.
- BAROMETRIC PRESSURE is sensed by capacitance or strain gage pressure transducers.
- SOIL WATER POTENTIAL is obtained using AC conductivity moisture blocks or analog output tensiometers.
- LEAF WETNESS is detected by a resistance grid.

Specialized applications include:

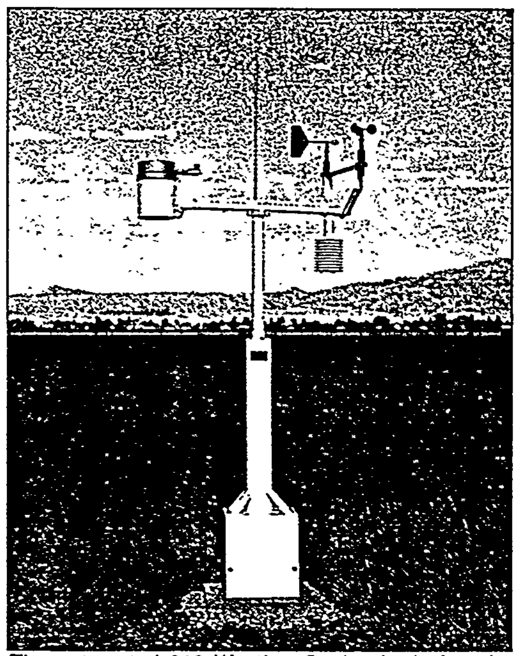
WIND POWER - WECS performance and site evaluation processing includes standard deviations, frequency distributions, wind speed and power histograms. Direct measurements of strain gages and pressure transducers are used to monitor turbines.

AIR QUALITY applications use the CR10's automatic control of calibration sequences and conditional averaging where invalid data taken during power failures, calibration intervals, or other conditions are excluded.

AGRICULTURE

In addition to meteorological monitoring, the CR10's versatility allows measurement of agricultural processes and equipment in applications such as:

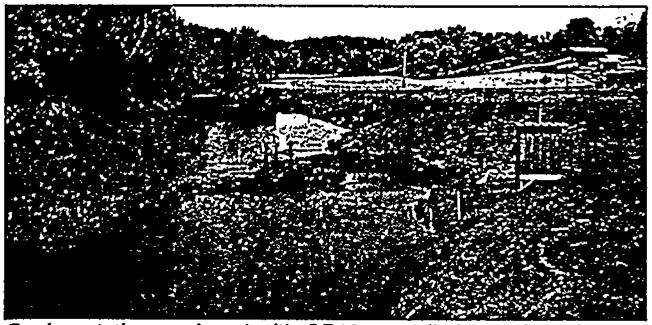
- plant water research
- canopy energy balance
- crop management decisions
- irrigation scheduling
- integrated pest management
- erosion studies
- machinery performance
- food processing/storage
- frost prediction
- plant pathology



The automated 012 Weather Station is designed for routine climatological monitoring. Features include a modular design, prewired sensors, and a standard program (Franklin County, ID).

HYDROLOGY

The CR10 is well-suited to remote, unattended monitoring of hydrologic conditions. Many hydrologic sensors interface directly to the CR10, including the new SDI-12 compatibles.



Gaging station equipped with CR10-controlled sampler takes samples based on flow (Little Platte River, WI).

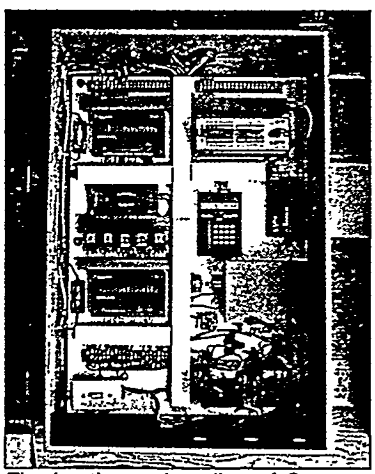
Typical hydrologic measurements:

- WATER LEVEL is read directly with an incremental shaft encoder, strain gage or vibrating wire pressure transducer. Some shaft encoders require a QD-1 Interface. Vibrating wire transducers require an AVW1 or AVW4 Interface.
- WELL DRAW-DOWN TESTS use a pressure transducer measured either logarithmically or at a rate based on incremental changes in water level.
- IONIC CONDUCTIVITY measurements use the AC excitation from one of the CR10's three switched excitation ports.
- WATER QUALITY samplers are controlled by the datalogger as a function of time, water level thresholds, or rate of change.
- ALARM AND PUMP ACTUATION is controlled through any of the eight digital I/O ports which operate external relay drivers.

INDUSTRY

The growing number of applications where the CR10 can inexpensively automate data collection and improve productivity and quality include:

- HVAC systems
- Vehicle/machinery testing
- Transportation
- Process control
- Water and sewage treatment
- Regulatory compliance
- Routine operations and maintenance
- Structural or fatigue analysis
- Energy management/ conservation
- Environmental testing



The heating and cooling of Campbell Scientific's factory is controlled by a CR10 and peripherals (Logan, UT).

More specifically, the CR10 can:

MEASURE input from

- load cells
- strain gages
- flow sensors
- speed sensors
- humidity sensors
- v/mV transducers
- temperature probes
- pressure transducers
- 4-20 mA transducers*

MONITOR conditions of

- valves
- filters
- boilers
- generators
- engines
- refrigerators
- appliances
- vehicles
- compressors
- turbines
- chillers
- pumps
- batteries
- transformers
- weighing scales

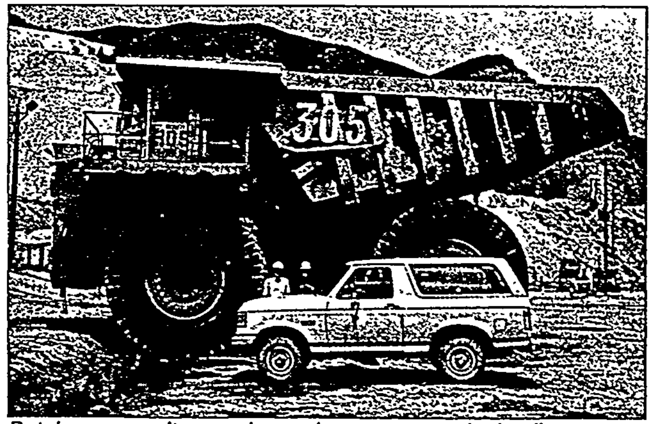
CONTROL based on time or measured parameters

- pumps
- solenoids
- motors
- resistive loads
- relays
- alarms

VEHICLE TESTING

The CR10 is ideal for applications requiring compact packaging such as:

- engine test cell monitoring
- durability testing
- fleet monitoring
- solar vehicle "C-studies"
- vehicle performance verification



Datalogger monitors and records pressure on hydraulic rams of haulage trucks (Kennecott Copper Mine, Oquirrh Mtns., UT).

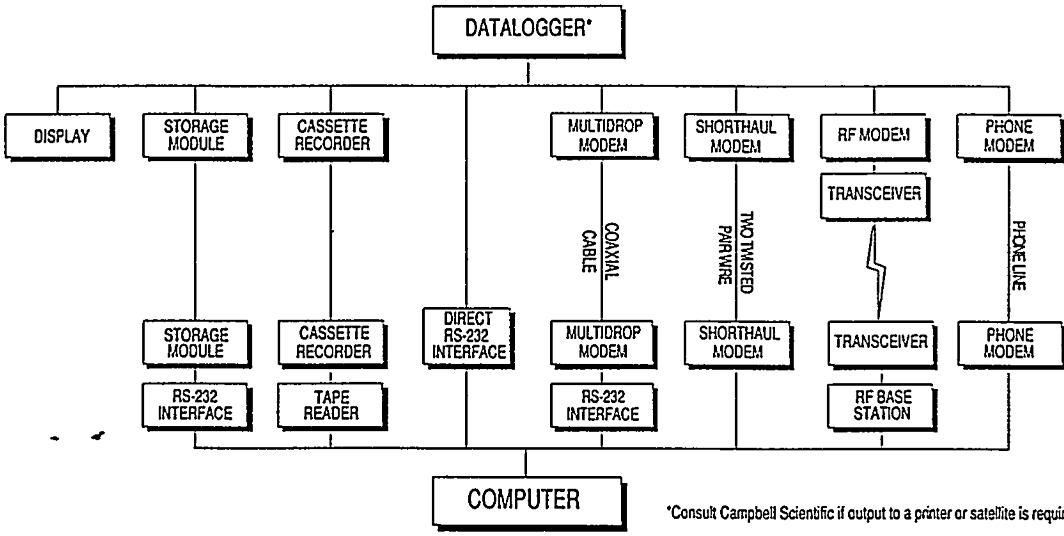
Common parameters for vehicle monitoring and durability testing are listed below:

- TEMPERATURE sensors include thermocouples and infrared (IR) detectors. The linearization for K-type thermocouples extends from -50° to 1370°C, allowing measurements from ambient to extreme exhaust temperatures.
- PRESSURE, FORCE, TORQUE, AND ACCELERATION measurements are accomplished with strain gage transducers.
- FUEL FLOW, ENGINE RPM, AND VEHICLE SPEED usually require magnetic pulse transducers or incremental encoders, either of which connect directly to the CR10 pulse counter inputs.
- THROTTLE POSITION is measured with potentiometers.
- TIMING EVENTS are output to the datalogger in period, pulse width, frequency, counts, or time intervals with the SDM-INT8 Interval Timer.
- FREQUENCY DISTRIBUTION HISTOGRAMS allow data compression over extended performance tests.
- RAINFLOW COUNTING HISTOGRAMS allow fatique analysis tests.

*Contact Campbell Scientific for proper wiring configuration.

Data Storage and Transfer

Up to 29,900 raw or processed data points can be stored in the CR10's memory. Data are transferred to a computer via one or more communications options including multidrop or short-haul modems, radios, phone lines, or satellite. On-site data retrieval options include direct line, storage module, cassette tape, display, or printer.



*Consult Campbell Scientific if output to a printer or satellite is required.

SOFTWARE

PC208 Datalogger Support Software supports telecommunications, programming, and data processing functions. With an appropriate communication link, PC208 provides two-way communication between Campbell dataloggers and IBM-PC or compatible computers. A Monitor mode allows real-time display of datalogger measurements.

DISPLAY

The CR10KD Keyboard/Display provides on-site review of data values and program instructions. On-site connection to a terminal or computer is also possible (Direct Line Options).

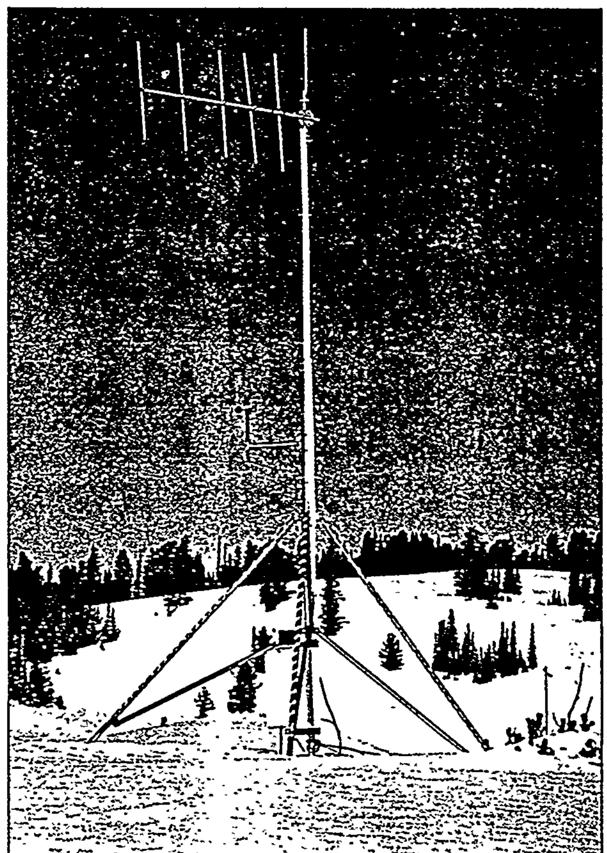
STORAGE MODULES

Rugged, battery-backed RAM storage modules reliably store data over a -35° to +65°C (extended values on request) temperature range. The SM192 or SM716 Storage Module (96K or 358K data values, respectively) can be left connected to the CR10 or carried to the field to retrieve data from the CR10's memory. Up to eight storage modules can be connected to one CR10. The SC532 Interface is used to transfer data or programs between the storage module and an MS-DOS computer. Consult Campbell Scientific if data playback to a non-MS-DOS computer is required.

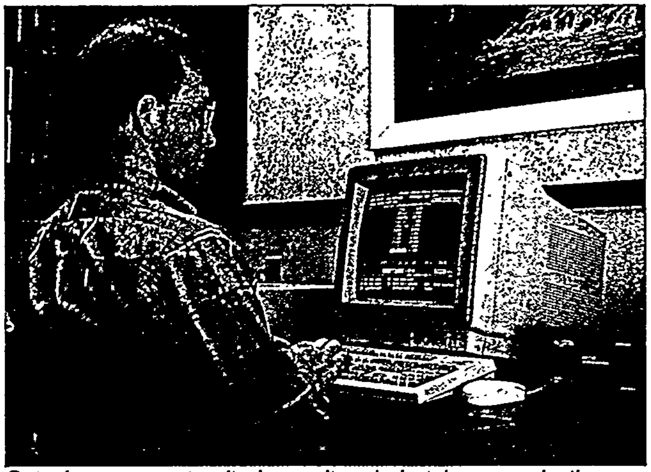
CASSETTE TAPE

The RC35 Recorder stores 180K data values on one side of a C60 cassette over a 0° to +40°C temperature range. Transfer of data from the CR10 to the RC35 requires the SC92A Interface.

Data transfer from tape to a computer is accomplished through either the PC201 Card or the C20 Cassette-Computer Interface. The PC201 requires an IBM PC/XT/AT or compatible computer. The C20 can be used with any computer having an RS-232 serial port.



Record temperature of -69°F was monitored via radio telemetry (Peter Sinks, UT).



Data from a remote site is monitored via telecommunications and PC208 Software.

DIRECT LINE OPTIONS

Direct Datalogger-to-Computer Interface
The SC32A RS-232 Interface supplies an optically isolated connection between the CR10 and a computer over distances up to 100 feet.

Short Haul Modems
Short haul modems provide local communication between the CR10 and a computer with an RS-232 serial port. The modem transmits data up to 6.5 miles over four-wire unconditioned line (two twisted pairs).

Coax Network
The MD9 Multidrop Interface links a central computer to over 200 dataloggers on a single coaxial cable. Total coax cable length can be up to three miles.

RADIO FREQUENCY (RF) COMMUNICATION

Campbell Scientific's RF communication system uses the RF95 modem and a low-powered transceiver at the remote station(s), and a transceiver connected to an RF232 Base Station at the computer site. Up to 255 stations can be interrogated over a single UHF or VHF frequency. Any station can serve as a repeater to extend the line-of-sight transmission of the base station.

TELEPHONE NETWORKS

Telephone communication links require a DC112 modem at the CR10 site and a Hayes-compatible 300 or 1200 baud modem at the calling end. Remote RF or MD9 networks are also accessible by telephone.

Channel Expandability

The following peripherals expand CR10 measurement or control capability. Contact Campbell Scientific regarding the suitability of these peripherals for your application.

SYNCHRONOUS DEVICES FOR MEASUREMENT (SDM's)

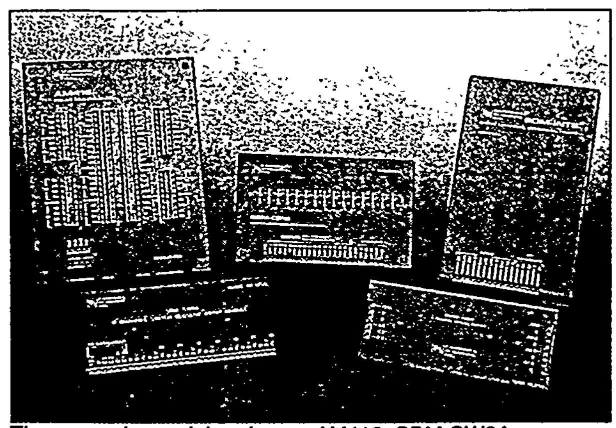
SDM's are addressable peripherals that expand digital control ports, analog output ports, and datalogger measurement capabilities. Up to 16 SDM's may be connected to three control ports on one CR10. SDM operation is controlled by datalogger instructions 101-104.

SDM-A04 Four Channel Continuous Analog Output Module provides four independent continuous analog outputs for proportional control or strip chart recording.

SDM-CD16 Control Port Module has 16 digital control ports with drivers to activate external relays, solenoids, or resistive loads. A manual override toggle switch is provided for each port.

SDM-INT8 Eight Channel Interval Timer expands the number of pulse count channels in the system and outputs processed timing data to the datalogger. Timing events are captured with ±1 microsecond resolution over a maximum range of 16.77 seconds. Output options include period, pulse width, frequency, counts, and interval time.

SDM-SW8A Pulse Counter is an 8-channel pulse count expansion for switch closure measurements. Channels can be individually configured for single-pole double-throw (SPDT), single-pole single-throw (SPST), or voltage pulse measurements. Output options include signal state, duty cycle, or counts.



The expansion peripherals are: AM416, SDM-SW8A, SDM-CD16, SDM-A04 and SDM-INT8

MULTIPLEXER

The AM416 Relay Multiplexer increases the number of sensors that can be measured by a CR10. The AM416 sequentially multiplexes sixteen groups of four lines at a time (a total of sixty-four lines). Compatible sensors include thermistors, thermocouples, potentiometers, load cells, strain gages, vibrating wires, and soil moisture blocks. Multiple AM416's can be controlled by a single CR10.

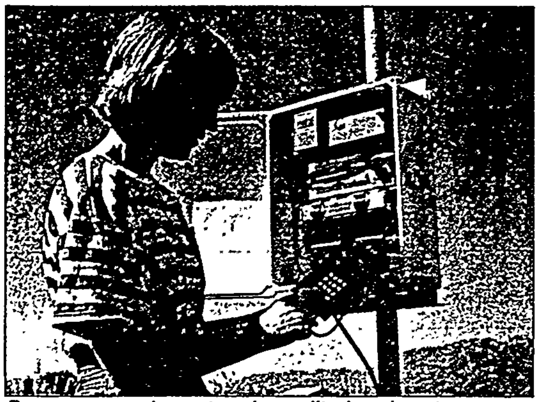
The Datalogger Program

The CR10's ability to make measurements, calculations, logical decisions, and phone calls stems from its internal program. The CR10's program can be extremely powerful, yet is composed of simple instructions. Knowledge of a high level programming language, such as FORTRAN or BASIC, is not required.

PROGRAM DEVELOPMENT

A CR10 program consists of a series of instructions designed to perform measurement, data processing, data storage, and logical control functions. To construct a program, the user selects application-specific instructions from a library of PROM-based instructions. These instructions, developed for data acquisition and control, allow the CR10 to measure most sensor types without the need for external signal conditioning.

Program development can be accomplished with a prompt sheet and a CR10KD keyboard. In addition, a prompt-driven, computer-based datalogger program editor (EDLOG) is available in Campbell Scientific's PC208 Datalogger Support Software.



Programs can be entered or edited and system performance verified on-site with a CR10KD.

INSTRUCTION FORMAT

Each CR10 program instruction is identified by a number. For example, Instruction 1 controls single-ended voltage measurements, Instruction 55 applies a 5th order polynomial to incoming data, Instruction 83 sets up an if/then statement, and Instruction 101 controls operation of an SDM device (SDM-INT8). The variety of instructions allows the user to select measurement, processing, data storage and control sequences that precisely fit his application.

The CR10's instructions can be grouped into four functional categories. A listing of the standard CR10 instruction set follows; more detailed information is available in the CR10 manual and prompt sheet.

INPUT/OUTPUT INSTRUCTIONS are primarily for sensor measurement, but also control and communicate with external devices. Some internal functions, such as control of the CR10's timer, are also classified as I/O instructions. Specific examples include:

- Single-Ended (SE) Volts
- Differential (DIFF) Volts
- Pulse Count
- Excite, Delay, SE Volts
- AC Half Bridge
- Full Bridge
- Three-Wire Half Bridge
- Excite, Delay, DIFF Volts
- Full Bridge with Measured Excitation
- Battery Voltage
- 107 Temperature Probe
- 207 RH Probe
- Thermocouple Temperature (SE)
- Thermocouple Temperature (DIFF)
- Platinum RTD Temperature
- Internal Temperature
- Time
- Signature
- Set Digital Ports
- Read Digital Ports
- Burst
- Excitation With Delay
- Timer
- Period Interval Measurement
- Vibrating Wire Measurement
- Set/Control External Device (e.g. SDM's)

PROCESSING INSTRUCTIONS allow data reduction, entry of simple algorithms, or conversion of raw data into engineering units. In the following instructions, X, Y, and Z are Input Locations where incoming data values or processed results are temporarily stored; F refers to a fixed value (constant).

- Z = F
- Z = X
- Z = Z+1
- Z = X+Y
- Z = X+F
- Z = X-Y
- Z = X*Y
- Z = X*F
- Z = X/Y
- Z = SQRT(X)
- Z = LN(X)
- Z = EXP(X)
- Z = 1/X
- Z = ABS(X)
- Z = FRAC(X)
- Z = INT(X)
- Z = X MOD F
- Z = X↑Y
- Z = SIN(X)
- Z = ARCTAN (X/Y)
- Spatial Maximum
- Spatial Minimum
- Spatial Average
- Scaling Array
- 5th Order Polynomial
- Saturation Vapor Pressure
- Wet/Dry Bulb Temp to Vapor Pressure
- Low Pass Filter
- Resistance from Bridge Output

OUTPUT PROCESSING INSTRUCTIONS process measured values, collected over time.

- Sample
- Average
- Totalize
- Maximize
- Minimize
- Histogram
- Windvector
- Real Time
- High/low Resolution
- Sample on Max or Min
- Redirect Output to Input Storage
- Standard Deviation

PROGRAM CONTROL INSTRUCTIONS allow logic based on time or data. They also control serial data output and CR10-initiated telecommunications.

- Subroutine
- Loop
- If X Compared to Y
- If X Compared to F
- If Flag/Port
- If Time
- If Case/Begin Case
- Else
- End
- Control Serial Data Output
- Initiate Telecommunications
- Send Serial Character

Once an instruction is selected, a set of associated parameters is queued in the datalogger's program memory. Each parameter controls a specific aspect of the instruction's operation. Depending on the versatility of the instruction, from 1 to 12 parameters are required. For example, the parameters associated with Instruction 2 (DIFFerential voltage measurement) are:

1 - REPS - Defines the number of times an instruction executes (allows one instruction to measure several identical sensors).

2 - RANGE - Defines the full scale range of the voltage to be measured. Ranges are ± 2.5, 7.5, 25, 250, and 2500 mV. Fast (272 µs), slow (2.72 ms), 60 Hz rejection, and 50 Hz rejection integration times are also selected with this parameter.

3 - INPUT CHANNEL - Defines the analog input channel that will make the first measurement.

4 - LOCATION - Defines the first Input Storage location.

5 - MULTIPLIER - Allows multiplication of data; for example, 1.8 is entered to convert a temperature measurement from °C to °F.

6 - OFFSET - Allows addition or subtraction of an offset value; for example, 32 is entered to complete the above temperature conversion.

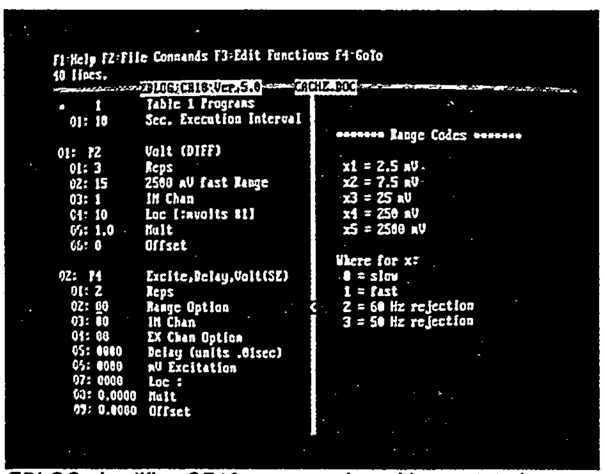
Once the parameters have been entered, the next instruction is selected. This procedure is followed until a specific program has been created. Following program entry, the datalogger checks for errors, then begins executing the program and acquiring data.

SCAN RATE, DATA STORAGE

The maximum rate at which the datalogger can execute its program is 64 times per second. (The maximum rate at which a single input can be measured is 750 samples per second.) After measurement and analog-to-digital conversion, data are directed to Input Storage locations which hold the measurement value for viewing, subsequent processing, or until transfer to Final Storage. Data can be selectively stored based on user-defined events or intervals and need not be tied to scan rate. Data remains in Input Storage until written over by subsequent measurement or processing.

EDLOG

Datalogger program development is supported by PC208 software (EDLOG). Help screens are available to define all instructions and parameter options. Input locations can be annotated with alphanumeric labels so that computer-monitored data is labelled. Once the program has been created, it can be downloaded to the CR10 directly, through telecommunications, or to a storage module for later downloading.



EDLOG simplifies CR10 programming with annotated instructions, parameters and labels.

SAMPLE PROGRAM

Every five minutes, the following program measures air temperature (°C) at six locations within a greenhouse. Critical maximum temperature is 30°C (86°F); if any temperature exceeds that threshold, a control port trips a relay that activates an exhaust fan. The average temperature value measured by each thermistor is recorded hourly.

SENSOR CONNECTIONS
In this example, sensor signal leads are connected to CR10 single-ended input channels 1 through 6, excitation leads are connected to excitation channel 1, and sensor grounds are connected to any analog ground terminal. Port 1 controls the exhaust fan.

			Program	Comments
	*	1	Table 1 Programs	*Executes the following program every 5 minutes.*
	01:	300	Sec. Execution Interval	
Measurement & Processing	01:	P11	Temp 107 Probe	*Measures six Model 107 Thermistors and places the results in Input Locations 1-6.*
	01:	6	Reps	
	02:	1	IN Chan	
	03:	1	Excite all reps w/EXchan 1	
	04:	1	Loc [:TEMP #1]	
	05:	1	Mult	
	06:	0	Offset	
	02:	P49	Spatial Maximum	*Analyzes the incoming data and places the highest temperature in Input Location 7.*
	01:	6	Swath	
	02:	1	First Loc TEMP #1	
	03:	7	Max Value Loc [:MAX TEMP]	
Exhaust Fan Control	03:	P89	If X <=> F	*Compares that temp. against 30°. If the measured temp. is higher, the exhaust fan is activated (or remains active).*
	01:	7	X Loc MAX TEMP	
	02:	3	>=	
	03:	30	F	
	04:	41	Set high Port 1	
	04:	P94	Else	*else, if lower*
	05:	P86	Do	*the exhaust fan is turned off or remains off.*
	01:	51	Set low Port 1	
	06:	P95	End	
Data Output	07:	P92	If time is	*The following data is ouput to Final Storage every hour:*
	01:	0	minutes into a	
	02:	60	minute interval	
	03:	10	Set high Flag 0 (output)	
	08:	P77	Real Time	*date, hour, minute;*
	01:	110	Day,Hour-Minute	
	09:	P71	Average	*average temp. measured by each sensor. (Each average is based on 12 measurements.)*
	01:	6	Reps	
	02:	1	Loc TEMP #1	
	10:	P	End Table 1	

With PC208 software and an appropriate telecommunications link, a researcher can monitor real-time data or control the exhaust fan remotely. Data transfer to a computer can be selected as binary, comma-delineated or printable ASCII.

Enclosures, Power Supplies, and Towers

A CR10 housed in a weather-resistant enclosure is engineered for data collection under extremely harsh conditions. A low power design allows the CR10 to operate one year on 7.0 Ahr, unregulated 12 volt source, depending on scan rate, number of sensors scanned, and external temperature. For field installations, Campbell Scientific can provide towers and mounting accessories.

ENCLOSURES

A protective enclosure for the CR10 is required in indoor or outdoor areas where dust, water, sunlight, or environmental pollutants are present.

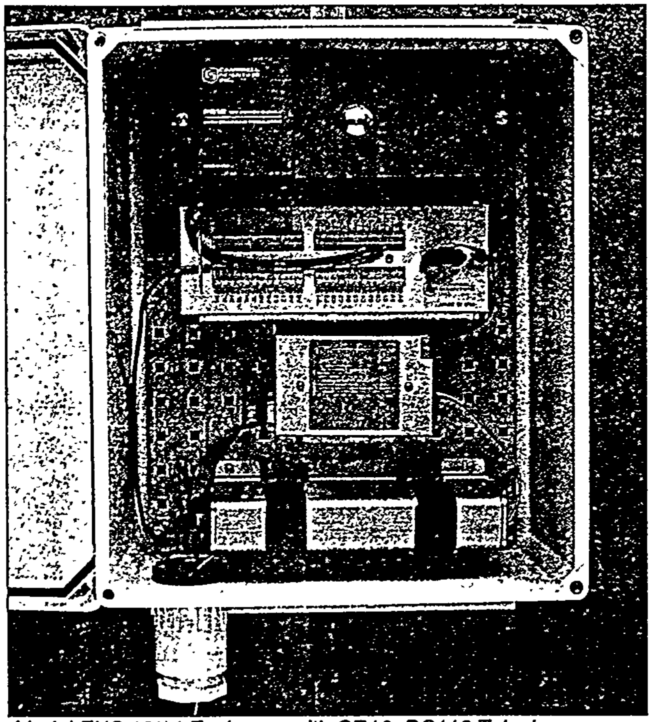
Our NEMA 4X enclosures are modified for cable entry and attach either to a flat surface or a vertical mast (1.00" to 1.25" IPS pipe). The white fiberglass-reinforced polyester enclosures are UV-stabilized and reflect solar radiation, reducing temperature gradients inside the housing. An internal mounting plate is prepunched for easy system configuration and exchange of equipment in the field. A lockable hasp provides additional security.

Two standard enclosures are available for the CR10, its power supply, and peripherals.

MODEL ENC 10/12 houses the CR10, a power supply, and one data retrieval peripheral such as a storage module. Inside dimensions are 12" x 10" x 4.5"; weight is 9 pounds.

MODEL ENC 12/14 houses the CR10, power supply, and one or more peripherals. Inside dimensions are 14" x 12" x 5.5"; weight is 12 pounds.

While these enclosures satisfy most application requirements, larger sizes can be specially ordered.



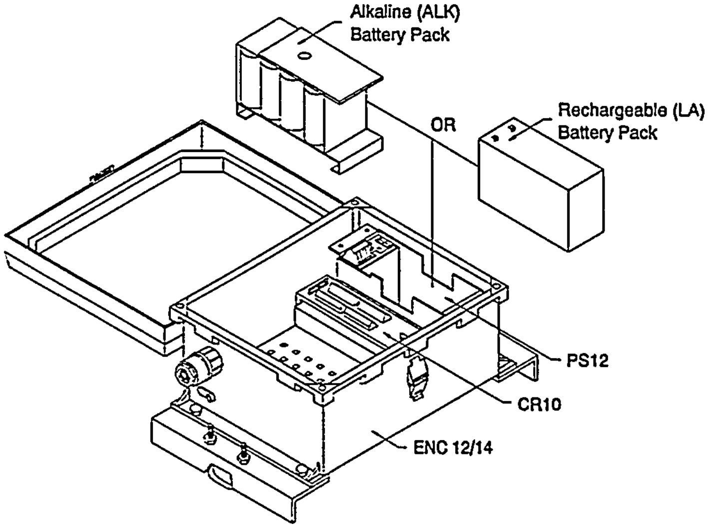
Model ENC 12/14 Enclosure with CR10, DC112 Telephone Modem, SM716 Storage Module, and PS12-ALK Power Supply

POWER SUPPLIES

The **PS12 Power Supply with Charging Regulator** accepts 16 to 26 VDC or AC input and provides a charging voltage to the 12 volt rechargeable battery option or to an external 12 volt battery. The battery options shown below are:

PS12-ALK contains eight non-rechargeable 'D'-cell alkaline batteries with a 7.5 Ahr rating at 20°C.

PS12-LA rechargeable battery option includes one 12 volt, 7 Ahr, rechargeable battery, and an AC transformer. It is float-charged with AC power or a solar panel.



SOLAR PANELS

MODEL MSX5 or MSX10 unregulated solar panel is used to float-charge the PS12-LA rechargeable battery option. Based on an illumination of 1 kW/m² and ambient temperature of 20°C, a peak voltage of 17 volts is supplied. Call Campbell Scientific if regulated solar panels for recharging customer-supplied 12 volt batteries are required.

TOWERS & MOUNTS

For field installations, Campbell Scientific manufactures durable tripods and towers designed for easy installation and adjustable placement of sensor mounts.

CM6 and CM10 TRIPODS are portable, sturdy tripods, six and ten feet, respectively. They can be staked down or mounted to a concrete pad.

10-METER TOWER is an aluminum instrument tower designed for fixed applications. Its triangular sections are bolted together with zigzag bracing. Models are available for cementing into the ground or mounting onto a roof. They can be further stabilized by guy wires.

Specifications

The following electrical specifications are valid for an ambient temperature range of -25° to +50°C unless otherwise specified.

ANALOG INPUTS

NUMBER OF CHANNELS: 6 differential or up to 12 single-ended. Each differential channel can be configured as two single-ended channels.

CHANNEL EXPANSION: The Model AM416 Relay Multiplexer allows an additional 64 single-ended channels to multiplex into four CR10 single-ended channels. Up to three AM416's can be connected to one CR10.

ACCURACY OF VOLTAGE MEASUREMENTS AND ANALOG OUTPUT VOLTAGES:
0.2% of FSR, 0.1% of FSR (0 to 40°C)

RANGE AND RESOLUTION: Ranges are software selectable for any channel. Resolution for a single-ended measurement is twice the value shown.

Full Scale Range	Resolution
± 2500 millivolts	333 microvolts
± 250 millivolts	33.3 microvolts
± 25 millivolts	3.33 microvolts
± 7.5 millivolts	1.00 microvolts
± 2.5 millivolts	0.33 microvolts

INPUT SAMPLE RATES: The fast A/D conversion uses a 0.25 ms signal integration time and the slow conversion uses a 2.72 ms signal integration. Two integrations, separated in time by 1/2 of an AC line cycle, are used with the 60 Hz or 50 Hz noise rejection option. Differential measurements include a second sampling with reversed input polarity to reduce thermal offset and common mode errors. Input sample rates are the time required to measure and convert the result to engineering units.

Fast single-ended voltage:	2.6 ms
Fast differential voltage:	4.2 ms
Slow single-ended voltage:	5.1 ms
Slow differential voltage:	9.2 ms
Differential with 60 Hz rejection:	25.9 ms
Fast differential thermocouple:	8.6 ms

INPUT NOISE VOLTAGE:

Fast differential	--- 0.82 microvolts RMS
Slow differential	--- 0.25 microvolts RMS
Differential with 60 Hz rejection	--- 0.18 microvolts RMS

COMMON MODE RANGE: ± 2.5 volts.

DC COMMON MODE REJECTION: > 140 dB.

NORMAL MODE REJECTION: 70 dB
(60 Hz with slow differential measurement).

INPUT CURRENT: 3 nanoamps maximum.

INPUT RESISTANCE: 200 gigohms.

EXCITATION OUTPUTS

DESCRIPTION: The CR10 has 3 switched excitations, active only during measurement, with only one output active at any time. The off state is high impedance.

RANGE: ± 2.5 volts.

RESOLUTION: 0.67 millivolts.

ACCURACY: Same as voltage input.

OUTPUT CURRENT: 20 mA @ ± 2.5 V; 35 mA @ ± 2.0 V; 50 mA @ ± 1.5 V.

FREQUENCY SWEEP FUNCTION: A swept frequency, square wave output between 0 and 2.5 volts is provided for vibrating wire transducers. Timing and frequency range are specified by the Instruction.

RESISTANCE AND CONDUCTIVITY MEASUREMENTS

ACCURACY: 0.015% of full scale bridge output, limited by the matching bridge resistors. The excitation voltage should be programmed so the bridge output matches the full scale input voltage range.

MEASUREMENT TYPES: 6-wire and 4-wire full bridge, 4-wire, 3-wire, and 2-wire half bridge. Bridge measurements are ratiometric and dual polarity to eliminate thermal emf's. AC resistance measurements use a dual polarity 0.75 ms excitation pulse for ionic depolarization, with the signal integration occurring over the last 0.25 ms.

PERIOD AVERAGING MEASUREMENTS

DEFINITION: The time period for a specified number of cycles of an input frequency is measured, then divided by the number of cycles to obtain the average period of a single cycle.

INPUTS: Any single-ended analog channel; signal dividing or AC coupling is normally required.

INPUT FREQUENCY RANGE:

Range Code	Peak to Peak Volts Required @ Max. Freq.*	Maximum Frequency
1	2 mV	8 kHz
2	3 mV	20 kHz
3	12 mV	50 kHz
4	2000 mV	200 kHz

*AC voltage; must be centered around CR10 ground

REFERENCE ACCURACY: ± 40 ppm.

RESOLUTION: ± 100 nanoseconds divided by the number of cycles measured. Resolution is reduced by signal noise and for signals with a slow transition through the zero voltage threshold.

TIME REQUIRED FOR MEASUREMENT: Signal period times the number of cycles measured plus 1.5 cycles.

PULSE COUNTERS

NUMBER OF PULSE COUNTER CHANNELS: 2 eight bit or 1 sixteen bit; software selectable.

MAXIMUM COUNT RATE: 2000 Hz, eight bit counter; 250 kHz, sixteen bit counter. Pulse counter channels are scanned at 8 Hz.

MODES: Switch closure, high frequency pulse, and low level AC.

SWITCH CLOSURE MODE
Minimum Switch Closed Time: 5 milliseconds.
Minimum Switch Open Time: 6 milliseconds.
Maximum Bounce Time: 1 millisecond open without being counted.

HIGH FREQUENCY PULSE MODE
Minimum Pulse Width: 0.002 milliseconds.
Maximum Input Frequency: 250 kHz.
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V.
Maximum Input Voltage: ± 20 V.

LOW LEVEL AC MODE
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs).
Minimum AC Input Voltage: 6 mV RMS.
Input Hysteresis: 11 mV.
Maximum AC Input Voltage: 20 V RMS.

Frequency Range:

AC Input (RMS)	Range
20 mV	1 Hz to 100 Hz
50 mV	0.5 Hz to 400 Hz
150 mV to 20 V	0.3 Hz to 1000 Hz

(Consult factory if higher frequencies are desired.)

DIGITAL I/O PORTS

8 ports, software selectable as binary inputs or control outputs.

OUTPUT VOLTAGES (no load): high 5.0 V ± 0.1V; low < 0.1 V.

OUTPUT RESISTANCE: 500 Ω.

INPUT STATE: high 3.0 V to 5.5 V; low -0.5 V to 0.8 V.

INPUT RESISTANCE: 100 kΩ.

SDI-12 INTERFACE STANDARD

This communication protocol, developed for microprocessor-based hydrologic and environmental sensors, is available as a software option in the CR10.

SENSOR CONNECTIONS: Digital I/O Port #8 (for asynchronous communication), 12V power, and ground. Up to ten SDI-12 sensors can be connected to a CR10.

TRANSIENT PROTECTION

All input and output connections to the CR10 module are protected using RC filters or transzorbs connected to a heavy copper bar between the circuit card and the case. The CR10WP Wiring Panel includes additional spark gap and transzorb protection.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303.

MEMORY: 32K ROM, 64K RAM.

DISPLAY: 8 digit LCD (0.5" digits).

PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, cassette, and RS-232 adapter. Baud rates selectable at 300, 1200, 9600 and 76,800. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).

CLOCK ACCURACY: ± 1 minute per month.

MAXIMUM PROGRAM EXECUTION RATE: System tasks initiated in sync with real-time up to 64 Hz. One measurement with data transfer is possible at this rate without interruption.

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 volts.

TYPICAL CURRENT DRAIN: 0.5 mA quiescent, 13 mA during processing, and 35 mA during analog measurement.

BATTERIES: Any 12 volt battery can be connected as a primary power source. Enclosures with power supply options are available.

PHYSICAL SPECIFICATIONS

SIZE: 7.8" x 3.5" x 1.5" - Measurement & Control Module; 9" x 3.5" x 2.9" - with CR10WP Wiring Panel. Additional room required for connectors.

WEIGHT: 2 lbs.

WARRANTY

Three years against defects in materials and workmanship.

Additional Information

ASSURANCE OF QUALITY

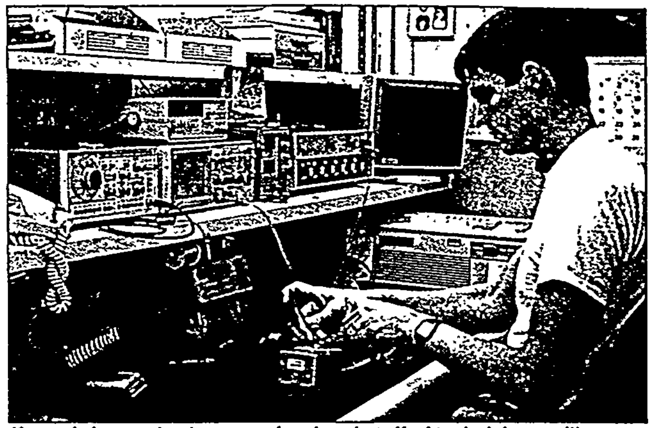
Campbell Scientific has been producing portable research-grade dataloggers for over fifteen years. Our commitment to quality is evidenced in the design and workmanship of the CR10 Measurement and Control System. Tailored for demanding field use, the CR10 features durable components, compact size, low power consumption, wide temperature tolerance, and easy field replacement.

After bench testing, all CR10 Modules are cycled between -35° to 60°C in an environmental chamber.

Every CR10 is calibrated and thoroughly tested to ensure consistent, dependable performance. The CPU, system components, and all I/O connections are tested. The datalogger's results are calibrated against NIST-traceable standards (National Institute of Standards and Technology, formerly known as NBS). A test report and calibration certificate including NIST traceable numbers are shipped with each CR10.

WARRANTY AND REPAIR

The CR10 is backed with a three-year warranty covering parts and labor. Our Mean Time Between Failure (MTBF) is over 50 years.



If repair is required, our professional staff of technicians will repair and recalibrate the CR10 to original specifications.

FOR MORE INFORMATION

For more detailed information on the products mentioned in this brochure, please contact Campbell Scientific sales or application engineers. Their technical and scientific backgrounds cover a wide range of fields including meteorology, agriculture, hydrology, industry, and vehicle testing. Trained in data acquisition, they can help develop your system configuration and give post-sale support if needed.

Pricing and ordering information is available from our price list or from our order entry staff. Contact our marketing department for information on customized training sessions or authorized representatives in your area.

Campbell Scientific's U.S. factory is located in Logan, Utah.

Please call us today; we would like to discuss your application needs with you.

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CR10 Instruction Set Options

The customer selects one of two OS10 PROM options (at no charge); both options contain the standard set of instructions. Differences in the OS10-0.1 and OS10-1.1 options, are listed below:

Instructions	OS10-0.1	OS10-1.1
23 Burst Measurement	X	
105, 106 SDI-12		X
64 Paroscientific		X
65 Bulk load		X

The selected option must be specified at the time of purchase, otherwise, the OS10-0.1 (default) PROM is supplied.

INSTRUCTION 23 - Burst Measurement

Burst Measurement increases the CR10 sample rate; one channel is sampled at a maximum rate of 750 Hz (once every 1.333 ms). The number of samples taken is limited by available memory. Instruction 23 makes voltage measurements on a series of single-ended or differential channels, with or without excitation.

INSTRUCTION 105 - SDI-12 Recorder

Communicates with up to ten sensors using the SDI-12 interface standard. The SDI-12 communication protocol was developed for microprocessor-based hydrologic and environmental sensors. Each SDI-12 sensor, set to a unique address between 0 and 9, responds with measurement data as commanded by the datalogger.

INSTRUCTION 106 - SDI-12 Sensor

The CR10 can act as an SDI-12 sensor by supplying measurement data to another device that issues the SDI-12 commands.

INSTRUCTION 64 - Paroscientific Processing

An instruction which simplifies the programming required to apply the calibration equation to the measurement of a Paroscientific pressure transducer with frequency outputs for both temperature and pressure.

INSTRUCTION 64 - Bulk Load

Loads eight fixed values into consecutive input locations.

New Features of OS10

- Instruction 66, Arctangent, is new.
- Instruction 69, Wind Vector, incorporates an EPA recommended algorithm for standard deviation of wind direction.
- On power-up, the CR10 can automatically load and run a program stored in an SM192 or SM716 Storage Module.
- RF communication protocol is set up for use with the RF95 modem.

Library Special PROMs

The above PROMs meet the needs of the majority of CR10 applications. Where some additional capability is required, library special PROMs are available at an additional charge. Some features of OS10 must be removed to make room for the special instructions. Library special modules include:

- The capability to save and load programs from cassette tape.
- Serial communications through control ports (300 or 1200 baud). May be used with some intelligent sensors.
- Fast Fourier Transform - The FFT is used to obtain the frequencies, relative magnitudes, and phases of various frequency components in a time varying signal. Instruction 60 performs a Fast Fourier Transform on a set of data contained in sequential Input Storage locations.
- Rainflow Histogram - An algorithm used in estimating cumulative fatigue damage. Strain measurements are processed to provide a two dimensional histogram. One dimension is the amplitude of the stress/strain cycles, the number of cycles within each user defined amplitude range are counted. The other dimension (optional) is mean value of the strain cycle.

Consult Campbell Scientific for further information regarding library special PROMs.

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APPENDIX L

CHARACTERISTICS OF EXISTING DATA SETS

Characteristics of Existing High Quality Data Sets to be Included in the Monitoring Program - Wind

Oahu Wind

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Anemometer Height	Contact Organization
Kahuku Upper	Opana	3/76 to 2/83	no	Sierra Inst. 3 cup anem., UH recorder	6 min. averages	37 feet	UHMET

Hawaii Wind

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Anemometer Height	Contact Organization
Kahua Ranch	Kahua Ranch	4/92 to present	yes	Zond WRE 2000	hourly averages	90, 140 feet	Kahua Ranch
Southpoint	Southpoint	6/87 to present	yes	SecondWind datalogger	hourly averages	unknown	Kamaoa Wind Farm

Maui Wind

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Anemometer Height	Contact Organization
McGregor Point	Maalaea	2/93 to present	yes	waiting for information	15 min. averages	10, 37, 64 meter	HECO
Puunene	Puunene	5/92 to present	yes	waiting for information	15 min. averages	10 meter	HECO

Kauai Wind

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Anemometer Height	Contact Organization
N. of Hanapepe	Robinson	7/85 to 4/88	no	Windrunner	approx. monthly	approx. 20 feet	Robinson
Port Allen	Port Allen Airport	2/92 to 1/93	yes	Met One #104 3 cup anem., #024 air foil sensor	6 min. & hr. avg.	30 feet	Measurement Tech.

Molokai Wind

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Anemometer Height	Contact Organization
Small Applications	West Molokai	2/92 to present	yes	Zond datalogger, 2 channel	hourly averages	90 feet	Zond

Characteristics of Existing High Quality Data Sets to be Included in the Monitoring Program - Solar

Oahu Solar

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Data Type	Contact Organization
N. Ewa Plain	Kunia	1989 to 1990	yes	LI-COR pyronometer; LI-COR quantum sensor	hourly averages	global	HSPA
Ewa Plain	Campbell Industrial	4/91 to present	yes	waiting for information	15 min. averages	global	HECO

Hawaii Solar

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Data Type	Contact Organization
Waikoloa	Kawaihae	12/90 to 8/92	no	waiting for information	15 min. averages	global	HECO
Waikoloa	Puuanahulu	1/92 to present	yes	waiting for information	15 min. averages	global	HECO
Waikoloa	Kiholo Bay	mid 91 to present	yes	Ascension Tech. RSR, CR10 datalogger	hourly averages	global; direct	Bakken
Waikoloa	Waimea	4/93 to present	yes	Ascension Tech. RSR, CR10 datalogger	hourly averages	global; direct	Bakken
Waikoloa	Mauna Lani Resort	4/93 to present	yes	Ascension Tech. RSR, CR10 datalogger	hourly averages	global; direct	Bakken
Keahole Point	Keahole	3/93 to present	yes	waiting for information	15 min. averages	global; diffuse	HECO
Keahole Point	Keahole	1985 to present	yes	2 Eppley 8-48 pyron.,1 w/band, CSi 21X datalogger since 4/92 LICOR LI200S pyron. as backup	6 min. totals	global; diffuse	NEL/Daniel
North Kohala	Kahua Ranch	10/92 to present	yes	Eppley pyronometer, CS21X datalogger	hourly averages	global	Zond

Maui Solar

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Data Type	Contact Organization
Puunene	Puunene	5/92 to present	yes	waiting for information	15 min. averages	global	HECO
Kihei	PVUSA	1990 to present	yes	CSi 21X datalogger; 2 Eppley PSP (horiz. & 22° tilt)	10 min. averages	global	PVUSA
Kahului	Maui Quarry	5/92 to present	yes	waiting for information	15 min. averages	global	HECO
Kahului	Mauinet #107	1983 to 1991	no	waiting for information	hourly averages	global	UH (Agronomy & Soil)

Kauai

Project Site	Data Site	Time Period	Current Collection	Equipment Description	Recording Interval	Data Type	Contact Organization
Barking Sands	McBryde Property	1/91 to present	yes	LICOR pyron., CR10 datalogger	hourly averages	global	McBryde

DEVELOPMENT OF RENEWABLE ENERGY

RESOURCE SUPPLY CURVES

Phase 2: Renewable Energy Resource Assessment And Development Program

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November 1995

prepared for:

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Energy Division
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SECTION 1. INTRODUCTION

RLA Consulting (RLA) has been retained by the State of Hawaii Department of Business, Economic Development, & Tourism (DBEDT) to conduct a Renewable Energy Resource Assessment and Development Program. This three-phase program is part of the Hawaii Energy Strategy (HES), which is a multi-faceted program intended to produce an integrated energy strategy for the State of Hawaii. This report summarizes the results of Phase 2 of the program, Development of Renewable Energy Resource Supply Curves.

PURPOSE

In Phase 1 of the program, suitable locations with development potential for renewable energy projects were identified and defined on each of the major Hawaiian islands. The emphasis for project identification was on utility-scale, grid-connected renewable energy projects. The purpose of Phase 2 is to develop resource supply curves based on the costs and performance of the potential projects identified in the first phase. The cost and performance estimates are based on current renewable energy conversion systems and realistic future projections with consideration of all the necessary components of a project, including financing, permitting, shipping, equipment integration, construction, operation, and maintenance. The results of Phase 2 include detailed cost and performance estimates for more than 230 potential renewable energy projects in the state as well as a user-friendly computer program that calculates the cost of energy for the projects and displays a graphical summary of the results of a specified query.

The information contained in this report is intended to summarize the baseline assumptions and present some illustrative results. The resource supply curve program was developed to provide the user with maximum flexibility to compare various options under differing conditions. As such, there is no single set of results. In addition, the objective of Phase 3 of the program is to concentrate on the integration and interpretation of the data. Therefore, limited conclusions have been drawn at this time. The final report for the project, completed in Phase 3, will include an integrated plan for incorporating renewables into the state's energy mix.

APPROACH TO DEVELOPING RESOURCE SUPPLY CURVES

In order to estimate costs and performance for renewable energy projects in Hawaii, RLA compiled the most current cost and performance data for each of the renewable energy conversion technologies to be evaluated in the project. Technologies included wind, solar thermal (trough and dishes), photovoltaics (fixed and tracking arrays), biomass electricity (including municipal solid waste), biomass fuel (both ethanol and methanol), hydroelectric, wave, and ocean thermal. For each potential project, costs and performance were estimated based on site-specific resource data and other information, then technology data worksheets were developed to summarize the detailed information for the project in an accurate and consistent manner.

A Resource Supply Curve (RSC) computer model was then developed to calculate the levelized cost of energy for each project based on the Electric Power Research Institute Technical Assessment Guide (EPRI TAG) methodology, a common set of economic parameters, and the data provided on the technology data worksheets. The results of the program are a graphical presentation of the cost of energy of each project versus the cumulative energy for all the projects meeting a specified criteria.

Resource supply curves provide a means for comparing costs of different projects within a specific technology and between technologies for each island or for the state as a whole. They can be used to determine which technologies can make the greatest energy contribution on a given island and to the state as a whole considering both the availability of the resource and the technology's economics. The primary value of resource supply curves is in comparing different generating options with each other given similar economic assumptions and evaluation methodologies. Because of changing economic conditions, financing assumptions, tax credit considerations, and costing methodologies, the values generated by the RSC program should not be used as absolute values outside the context of the program (i.e., for contracting purposes or pricing justification). Similarly, the values should not be compared against other non-renewable generating options unless the cost of energy is calculated using a consistent approach and methodology.

REPORT ORGANIZATION

This report is organized into three main sections. Following the introduction, Section 2 summarizes the approach and assumptions used to estimate the costs and performance for each of the potential renewable energy projects evaluated. Section 3 discusses the economic basis for calculating the cost of energy and contains illustrative results and examples from the RSC program. The technology data worksheets, guidelines for using the RSC computer model, and illustrative results for each island and technology are included in appendices.

SECTION 2. COST AND PERFORMANCE ESTIMATES

In developing cost and performance estimates for each of the projects evaluated in this program, RLA combined state-of-the-art knowledge regarding the status of the technology and its future implementation with a practical perspective on the elements necessary to bring a project from its conception stage to successful operation in Hawaii. The results are realistic estimates bounded by optimistic and conservative ranges to represent the uncertainty associated with the technology development or the resource availability.

OVERALL APPROACH

For each potential project location identified in Phase 1 of the Renewable Energy Assessment and Development Program, a number of possible project sizes were evaluated. The size and number of projects evaluated at each location was based on several factors. The size and characteristics of the land parcel available for potential development was the primary consideration. In some cases, only one project size was evaluated because land constraints prohibited consideration of other sizes. In most cases, however, multiple project sizes were evaluated because sufficient land was available to support larger projects.

The capacity of the existing transmission lines was the next criteria used to define potential project sizes. For most locations, transmission upgrades were required for projects above a certain size. In these cases, the largest project that could be installed at a particular site without costly transmission upgrades was evaluated. Larger projects (which included the costs of transmission upgrades) were also evaluated as appropriate.

The size of the utility grid on each island was also a consideration. For islands other than Oahu, projects larger than 30 MW may be difficult to develop because of the size of the existing utility grid and the projected demand growth. As a result, 30 MW project sizes were evaluated for sites in which other constraints did not define the size. On Oahu and for a few cases on the other islands, projects of 50 MW or larger were evaluated. This is justified on Oahu because of the size of the utility grid. Large projects were evaluated on the other islands to provide additional data on the economies of scale, and to account for any future changes in demand due to factors such as island interconnection, large load growth, or load profile changes.

For most technologies, two conceptual plant designs were developed. One design was based on plant components that are commercially available for installation in 1995 projects (current technology). The other design was based on components that are realistically expected to be commercially deployed by the year 2005 (future technology). In the case of technologies that have not been commercially deployed, estimates were made for only the future scenario. For mature technologies in which no substantial technological advances are expected, estimates were developed for only the current scenario.

In order to account for the uncertainty in cost and resource projections, three estimates (representing optimistic, nominal, and conservative cases) were made for each potential project and for both stages of technology development (current or future). As a result, a total of six cost and energy estimates were made for each potential project location and size for the majority of the technologies evaluated.

The optimistic, nominal, and conservative cases differ from each other because of uncertainty in energy production, project costs, or a combination of both. Energy production estimates vary to reflect the uncertainty of the resource, as well as the potential variation in energy conversion efficiency of the technology. Cost estimates vary to reflect uncertainties in factors such as the development pace of the technology, changes in market conditions, variations between suppliers and developers, and other uncertainties inherent in estimating project costs in an environment where few projects of this type have been completed. The nominal value represents the best estimate but is not necessarily the mean value of the range.

Project performance estimates are based on the conceptual plant designs, potential project sizes, and the best available resource data. For wind and solar projects, additional data collection is underway at a number of the sites. Performance estimates for these technologies will be updated when better resource data are available and the results will be included in the Phase 3 report. In all cases, gross energy estimates were calculated and energy losses were assumed to account for factors such as line losses and downtime. The net energy estimates are the amount of energy expected to be delivered to the utility grid.

Costs on the technology data worksheets are estimated in a manner that is consistent with the EPRI TAG method of evaluating utility generating alternatives and are stated in 1995 dollars. Only the total capital costs, the total annual expenses, and the net annual energy production are used in the resource supply curve model. The detailed itemization of costs is given on the worksheets to provide supporting documentation for the totals, allow comparison between different projects, and ensure consistency. A description of the cost components follows.

Capital Costs include Total Plant Costs and Initial Costs. Total Plant Costs are made up of five components: process capital, general facilities capital, engineering and overhead, project contingency, and process contingency. Each of the components of the Total Plant Costs and Initial Costs is discussed in more detail below:

> *Process Capital* is the total constructed cost of all on-site processing and generating units, including all direct and indirect construction costs. The estimates have been made based on site layouts consistent with the geographic and topographic constraints at each project location. Storage facilities and equipment required for fuel delivery and waste removal (if any) are included. Major equipment costs are based on recent equipment purchases whenever possible, and other equipment costs have been scaled based on costs from similar facilities. Labor costs were estimated from comparison with similar projects and have been adjusted to account for site constraints and local labor rates.
>
> *General Facilities Capital* includes the cost of such facilities as roads, office buildings, shops, etc., that are required for plant operations, but which do not necessarily directly contribute to the production of the energy end product.
>
> *Engineering and Overhead* is assumed to be 10% of the process capital.
>
> *Project Contingency* is assumed to be 10% of the sum of the above three categories. Project contingency is meant to cover the cost of additional equipment or unexpected costs that may be overlooked in a preliminary cost estimate.
>
> *Process Contingency* is defined in the EPRI TAG as a capital cost contingency factor applied to a new technology in an effort to quantify the uncertainty in the technical performance and cost of the commercial-scale equipment. In this study, process contingency is accounted for by the variation between the conservative and optimistic estimates of cost and performance. As such, no additional amount for process contingency has been added to the cost estimates.
>
> *Initial Costs* reflect the cost of supplies needed on hand to begin operating the power plant. Initial or start-up costs include the equivalent of one month's operating costs, 25% of one month's fuel cost (if applicable), 2% of the Total Plant Cost (a simplifying assumption from the EPRI TAG) to account for any last minute changes, and the capital required for inventory of spare parts, fuel on hand, or other miscellaneous expenses.

Annual Expenses include the annual costs associated with project operation which are divided into two basic categories: fixed and variable. Variable costs are directly associated with how much energy is produced, while fixed costs are unaffected by the energy production. The annual operating costs include an allotment for periodic component replacements levelized on an annual basis.

Due to the high value of land in Hawaii, it is most likely that land for any potential renewable energy project will be leased rather than purchased. Land lease costs are included as a fixed operating cost. Lease rates depend on the land's value for other uses and the land owner. For consistency purposes, land lease costs were estimated for different categories of land ownership including private, state, federal (military), and Hawaiian Homes land, and these values were applied consistently among projects.

In order to adjust U.S. mainland costs to Hawaii, cost indexes were applied based on the R.S. Means Building Construction Cost Data, 1993.[1] This document specifies indexes for materials and installation of various construction-related projects for use in adjusting costs between U.S. cities. Additional cost information on labor rates, equipment rental, and construction processes was obtained from construction companies involved with projects on each of the Hawaiian islands and this information was applied as appropriate.

Permitting costs were estimated based on discussions with county, state, and federal permitting offices in Hawaii and they vary based on the technology type and the zoning classification of the project site. Shipping costs are based on recent quotations and actual equipment weight and include delivery of the equipment to the project site.

Transmission costs were based on discussions with Hawaiian Electric Company, recent studies of transmission upgrades, and costs for other utilities adjusted to Hawaii conditions.

TECHNOLOGY-SPECIFIC ASSUMPTIONS

The following sections describe the assumptions that were made for each of the renewable energy technologies evaluated in this study. For each technology, the technology status, performance assumptions, and cost basis are outlined.

WIND

Technology Status: Wind energy is a technology that has been commercially deployed on a large-scale basis for more than ten years. However, technology advances continue to improve the performance and reliability as well as reduce the cost of the technology. Research through the U.S. Department of Energy (U.S. DOE), European Community, and others is aimed at numerous technological advances to further reduce the cost of energy from wind projects. For this study, current cost and performance estimates are meant to reflect wind technology that is currently being bid for projects that will be installed in the 1995 time frame.

Future cost and performance estimates were scaled from current estimates based on technology advances that are currently under development and expected to be achievable in the next ten years. These developments include: improved aerodynamic performance, increased rotor size, higher installed capacity per turbine, advances in variable-speed technology, improved controls, and the cost advantages associated with mass production. Some improvements are also incorporated to account for increased industry experience that will reflect the incremental lessons learned in project construction, management, and operations and maintenance.

Performance Assumptions: Estimates of the wind resource at specific sites were based on historical data in the vicinity of the site, new data being collected under the Renewable Energy Resource Assessment and Development Program, and RLA's judgment. The variations between optimistic,

1 Means Building Construction Cost Data, 50th Edition, R.S. Means Company, Inc., 1991.

nominal, and conservative performance estimates account for uncertainty in the resource data. A power curve for a hypothetical wind turbine was used to estimate per-turbine production at each site. In addition, the following assumptions were made:

- Hourly wind resource data were used for each site where high-quality data were available. In the absence of actual hourly data, site wind speed distributions were determined based on a Weibull distribution ($k = 2.9$) and estimated average annual wind speeds. The shape of the Weibull distribution was matched to the shape of distributions from typical Hawaii sites for which high-quality data were available. The average annual wind speeds were estimated based on the nearest available data and results from the on-going monitoring program.

- Estimated energy losses were determined on a site-specific basis and range from 18%-28%, depending on the site conditions and potential project layouts (particularly the spacing between turbines). Energy losses account for blade soiling, array effects, control inefficiencies, turbulence, downtime, and line losses.

- A hypothetical wind turbine representative of commercially available technology was used for project layout purposes. It was assumed that the turbine had a 30 meter rotor diameter and was mounted on a 120 foot tower.

Cost Basis: Itemized costs were developed for each nominal current technology case using the best currently available information. Future costs were estimated based on projections by U.S. DOE, EPRI, and others. The following assumptions were made:

- Equipment costs are based on publicly available information from equipment manufacturers and recent bids for actual projects. Balance-of-station costs are based on installation information on operating projects in California, adjusted to account for costs in Hawaii and expressed in terms of 1995 dollars.

- Parametric costs were developed for construction based on three different soil types: lava, rocky, and dirt.

- Parametric costs were developed for balance-of-station costs and construction costs based on types of terrain to account for larger spacing between turbines and ease of construction.

- The size of the control buildings, monitoring systems, and support equipment varied by project size.

- Turbine and tower costs were varied to reflect larger production run discounts. A discount was applied to the equipment costs for projects larger than 50 MW and a surcharge was added to projects 5 MW or smaller.

- The majority of balance-of-station costs are assumed to be proportional to the number of wind turbines in the project. Costs for roads, grading, and electrical interconnection are scaled according to the ruggedness of the terrain and the soil type.

- Land and permitting costs vary according to land ownership and zoning.

PHOTOVOLTAICS

Technology Status: Although a large market exists for photovoltaics for remote power applications and consumer products, there is limited experience with large-scale photovoltaic installations for bulk electricity generation. However, there are multiple demonstration projects installed throughout the U.S., including a PVUSA (Photovoltaics for Utility Scale Applications) satellite project located near Kihei on the island of Maui. For this study, current cost and performance estimates are based on experience with recent demonstration projects. Research is concentrated on increasing module efficiency and improving manufacturing processes. Future costs and performance estimates are scaled from current technology values based on industry estimates of improved efficiency and the cost advantages associated with mass production.

Performance Assumptions: Typical Meteorological Year (TMY) weather data from Barber's Point, Oahu, serves as the basis for the annual energy production estimates. TMY data are a compilation of "typical" climatic months selected from a 23 year database. The data are in hourly format and designed to provide an accurate portrayal of the long-term average climatic regime. The weather data consist of direct normal beam irradiance, global horizontal irradiance, ambient dry bulb temperature, and wind speed. Indices were used to extrapolate the results from Barber's Point to other project sites in Hawaii. The indices were based on historical climatic data in the vicinity of the site,[2] new data being collected under the Renewable Energy Resource Assessment and Development Program, and engineering judgment. The variations between optimistic, nominal, and conservative performance estimates account for uncertainty in the resource data. In addition, the following assumptions were made:

- Both fixed and tracking photovoltaic systems were evaluated. Fixed systems were assumed to face due south at a 15 degree tilt angle. For tracking systems, a north-south, single-axis tracking array structure was assumed.
- Current technology assumes a 13.5% efficient crystalline module at 1000 W/m^2 and 20°C.
- Future technology assumes a 17% efficient crystalline module at 1000 W/m^2 and 20°C.
- A ground cover ratio of 70% was assumed.
- Energy losses are assumed to be approximately 16%, which includes consideration of inter-array shading, cabling losses, and power conditioning efficiency.
- The array field layouts are designed to minimize wiring and associated power losses, and the array field layout is optimized on the basis of inter-array shading.

Cost Basis: The following cost assumptions were made:

- Equipment costs are based on recent information from equipment manufacturers and experience with demonstration projects.
- Parametric costs were developed for foundations and construction based on three different soil types: lava, rocky, and dirt.
- The array structure costs are based on designs used extensively in recent utility PV installations.
- Module costs vary to reflect production run discounts. In addition, future module costs are reduced to represent mass production cost advantages due to a larger market for PV systems.
- For future technology, infrastructure costs were reduced due to the increased efficiency of the modules (fewer modules are necessary for the same size project).
- Land and permitting costs vary according to land ownership and zoning.

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2 Kearney, D. *Solar Electric Generating System (SEGS) Assessment for Hawaii,* State of Hawaii Department of Business, Economic Development & Tourism, Honolulu, Hawaii, December 1992.

SOLAR THERMAL

Technology Status: Three main types of collectors have been used for solar thermal systems: parabolic troughs, parabolic dishes, and central receivers. Central receivers were not evaluated in this study because of land use constraints in Hawaii and the status of the technology. Parabolic trough systems are the most mature solar thermal technology and they have been extensively deployed in commercial projects in California. Prototype parabolic dish systems have been operated on a limited basis. However, extensive research and development has resulted in continuing component improvements and expected cost reductions. Current technology cost and performance information for solar trough systems is based on experience with recently installed commercial projects. Current technology cost and performance information for solar dish systems is based on projections for Dish-Sterling systems currently under development and expected to be commercially available in 1995-97. Future technology estimates are scaled from the current estimates based on knowledge of technological advances that are currently under development and expected to be achievable in the next ten years.

Performance Assumptions: Typical Meteorological Year (TMY) weather data from Barber's Point, Oahu, serves as the basis for the annual energy production estimates. TMY data are a compilation of "typical" climatic months selected from a 23 year database. The data are in hourly format and designed to provide an accurate portrayal of the long-term average climatic regime. The weather data consist of direct normal beam irradiance, global horizontal irradiance, ambient dry bulb temperature, and wind speed. Indices were used to extrapolate the results from Barber's Point to other project sites in Hawaii. The indices were based on historical climatic data in the vicinity of the site,[3] new data being collected under the Renewable Energy Resource Assessment and Development Program, and engineering judgment. The variations between optimistic, nominal, and conservative performance estimates account for uncertainty in the resource data. In addition, the following assumptions were made:

- Performance of solar trough systems is based on the operation of the Solar Electric Generating Station (SEGS) plants in California. Future performance for trough systems is based on industry projections and engineering judgment of factors such as expected solar field improvements.
- Performance of the solar dishes is based on prototype testing results and performance models. Future performance is increased by approximately 5% to account for increased efficiency.
- For solar dishes, utility-scale units of 25 kW are assumed.
- For solar troughs, north-south, single-axis tracking is assumed.

Cost Basis: The following cost assumptions were made:

- Equipment costs for the solar trough systems are based on data from the SEGS plants in California and recent quotes on major equipment from vendors.
- Cost assumptions for the solar dish systems are based on research conducted for the U.S. DOE by SAIC. Future costs are estimated based on knowledge of research and development programs, both within the U.S. and abroad.
- Parametric costs were developed for foundations and construction based on three different soil types: lava, rocky, and dirt.

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[3] Kearney, D. *Solar Electric Generating System (SEGS) Assessment for Hawaii*, State of Hawaii Department of Business, Economic Development & Tourism, Honolulu, Hawaii, December 1992.

- For solar dishes, future cost estimates are reduced to represent cost advantages due to higher production rates because of an anticipated larger market.
- Land and permitting costs vary according to land ownership and zoning.

HYDROELECTRIC

Technology Status: Hydroelectric is a mature technology. There are few appreciable differences between the types of projects that would be installed in 1995 and those that would be installed in the year 2005. As a result, only current technology projects are evaluated in this study. New projects are expected to have lower operation and maintenance costs than existing projects resulting from semi-automatic operating strategies and improvements in designs.

Completing the permitting and environmental requirements of hydro projects in Hawaii has proven to be difficult due to the high value placed on natural resources and competing uses. For these reasons, and due to the porosity of the ground soil, hydroelectric projects developed in Hawaii are likely to be run-of-the-river rather than storage type projects.

Performance Assumptions: A computer simulation model was used to predict hydroelectric performance based on series resource data, head, pipe sizes, and turbine type. The model accounts for frictional losses in the penstock, operational restrictions, and turbine/generator efficiencies. Water resource data were based on either information from actual project proposals or hydrology reports completed for nearby hydroelectric facilities. Information on rainfall estimates and soil characteristics was also examined. Allowances were made for water bypass to maintain minimum streamflows to maintain river ecology. Energy losses account for power transformation and transmission to the utility grid.

Cost Basis: Cost estimates are based on recent experience with hydroelectric project development both within Hawaii and at other mainland locations.

BIOMASS

Technology Status: There are a number of methods for converting biomass to energy. In this study, both the conversion of biomass to electricity and the conversion of biomass to liquid fuel (both ethanol and methanol) were evaluated. Biomass fuel sources include energy crops of either trees, grass crops and organic waste (agricultural and/or municipal solid waste). The biomass conversion technologies selected for evaluation in this study are based on the their applicability to Hawaii's feedstocks and conditions.

There is extensive experience in Hawaii converting biomass to electricity. Current biomass-to-electricity technology is relatively mature. Biomass-to-electricity projects utilizing bagasse and organic waste as a fuel source are currently in operation in Hawaii. These projects use a biomass-fired boiler to drive a steam turbine/generator with either tree crops, sugar, or organic waste as a fuel source. This conversion process was used as current technology for this study.

Future projects converting biomass to electricity are likely to use biomass fixed bed gassifiers integrated with open cycle gas turbines[4] and this type of conversion technology was assumed for the future biomass-to-electricity projects evaluated in this study. Examples of gassification technology are currently being demonstrated.

For biomass-to-liquid-fuel projects, only future conversion technologies were evaluated. The process of converting some types of biomass to ethanol is commercially developed in parts of the world. The conversion of corn to ethanol is currently practiced on the U.S. mainland and sugar cane is converted to ethanol in Brazil; however, these technologies are not considered to currently be commercially

[4] California Energy Commission. *1992 Energy Technology Status Report*, 1992.

viable in the Hawaiian environment. Future biomass-to-ethanol projects will incorporate advanced techniques such as acid pre-treatment, simultaneous saccharification and fermentation, distillation, and co-product utilization.

The production of methanol from biomass is another possible future technology. While this process is not yet commercially available, technology is being developed that will produce methanol from biomass through a process of biomass gassification coupled with conditioning and catalytic reactions.

Performance Assumptions: Biomass crop yields were estimated using the Hawaii Natural Resources Information System database and data from the Hawaiian Sugar Planters' Association. Estimates of the annual generation of organic waste material were obtained from a recent survey of Hawaii's organic waste potential that was completed for DBEDT by Unisyn.[5] Additional assumptions include:

- Feedstock supplies were calculated for plant sizes at 25 MW or 25 MGPY (million gallons per year) and 50 MW or 50 MGPY.

- The production of tree and grass crops at the same site were mutually exclusive because the same land area would be required for either crop. Combinations of either tree or grass and organic waste, however, are possible and are used to achieve the minimal amount of feedstock for the two targeted plant capacities.

- A 7 year growth cycle is assumed for tree crops based on experience and research on short-rotation tree crops in Hawaiian conditions. The land parcels with the highest tree yields were utilized first to meet the feedstock requirements.

Cost Basis: Cost estimates for biomass installations were based on the results of recent studies. Assumptions include:

- Plantations are assumed to be located on existing agricultural lands planted in crops. Conversion facilities are assumed to be located at the site of existing conversion or processing facilities because the usable agricultural lands currently have existing facilities associated with them.

- Site preparation, planting, and harvesting are assumed to be conducted continuously.

- Existing main and access roads are usable for biomass purposes and therefore no additional costs were included. New feeder roads were assumed as required.

- Costs associated with seeding and planting, fertilizer applications, mowing, etc., are based on current practices and experience in Hawaii.

- Land and permitting costs vary according to land ownership and zoning. Land lease fees for agricultural land are based on existing practices.

- A revenue stream resulting from tipping fees for organic waste disposal is assumed for facilities using municipal solid waste. Actual tipping fees or those proposed in recent solid waste management plans are used for Maui, Kauai, and Hawaii ($17.00, $19.50, $17.00 per fresh ton, respectively). On Oahu, a tipping fee of $25.00 per fresh ton is assumed. Although higher tipping fees are currently in effect on Oahu (approximately $54.00 per fresh ton), this level of payment is due largely to the costs associated with the operation and payment of debt on the incinerator/RDF system (H-POWER).

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5 Unisyn Biowaste Technology. *Feasibility Study of Organic Waste Conversion Facilities in Hawaii, Draft Report*, prepared for the Department of Business, Economic Development & Tourism, 1993.

- The cost of energy for biomass fuel projects was converted into cents/kWh to allow for comparison to electricity generating biomass projects.

WAVE

Technology Status: There are a number of different wave energy conversion devices currently under development. For this study, a heaving buoy, hose pump system was assumed based on its economic benefits when compared with other wave energy conversion systems.[6] Because this technology is currently in the demonstration stage, only future technology projects were evaluated.

The reference design consists of one or more star-shaped clusters of buoys, moored in an 80 m water depth. Each star contains 60 buoys and six collecting lines arranged symmetrically around an underwater habitat, which houses a 10 MW turbine generator.

Performance Assumptions: The resource data used to estimate the performance of potential wave energy projects are based on a review of the available statistical summaries of visual, hindcast, and measured wave data in Hawaii. The performance was based on the best fit of the projected absorption efficiency of buoy/pump modules in random waves to the results of different numerical model simulations. The variation between optimistic, nominal, and conservative estimates accounts for the variation in the model results. The following assumptions were made:

- The conversion of absorbed power to offshore electric power assumed 90% fluid power transfer efficiency from the buoys to the underwater habitat and 90% turbine generator efficiency.

- Line losses vary with assumed line sizes and sea-to-shore distance. Sea-to-shore distances vary from 1.5 km to 8 km, depending on location.

Cost Basis: Costs are based on conceptual designs developed for a 30 MW facility off the northern California coast, adjusted to account for costs in Hawaii. The following cost assumptions were made:

- Equipment costs are based on quotes from component suppliers and lease rates for an onshore fabrication yard and offshore deployment equipment.

- A 30% contingency for weather delays was applied to all offshore equipment mobilization and deployment activities.

- Operation and maintenance costs were based on experience with offshore tanker terminals.[7]

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6 Hagerman, G. and F.P. Heller. "Wave Energy: A Survey of Twelve Near-Term Technologies," *Proceedings of the International Renewable Energy Conference*, Honolulu, Hawaii, September 1988, pp. 98-110.
Hagerman, G. "Wave Power," *Encyclopedia of Energy Technology and the Environment*, edited by A. Bisio and S.G. Boots, New York: John Wiley & Sons, Inc., 1994 (in press).

7 SEASUN Power Systems. *Wave Energy Resource and Economic Assessment for the State of Hawaii*. Energy Division of the State of Hawaii, Department of Business, Economic Development & Tourism, 1992.

OCEAN THERMAL ENERGY CONVERSION (OTEC)

Technology Status: Hawaii has been a leader in the research and development of ocean thermal energy conversion technology. For this study, the basic conceptual design was assumed to be a land-based, closed-cycle, ammonia power system plant. Because this technology is currently in the demonstration stage, only future technology projects were evaluated in this study. Cost and performance data are based on research conducted and published by PICHTR in cooperation with U.S. DOE and work conducted in the mid-80s on the DOE OTEC Pilot Plant Program.

Performance Assumptions: The ocean thermal resource is based on the bathymetry, which is a measurement of the depth of water in the ocean, and by the seasonal surface temperature variations. The following performance assumptions were made:

- The conversion efficiency, availability, and parasitic losses were based on research projections and were varied among the optimistic, nominal, and conservative cases to account for uncertainty in the technology.

- At Kahe Point, performance was assumed to be enhanced by the warm water discharged from HECO's onshore thermal power plant at that site.

Cost Basis: All cost estimates for the conservative cases were based on the detailed work breakdown structure and associated cost estimate prepared by Ocean Thermal Corporation and its subcontractors, adjusted to 1995 dollars.[8] All costs estimates for the nominal and optimistic cases are derived from more recent work conducted by PICHTR.[9] Adjustments to these costs were made as appropriate in order to ensure consistency in approach and costing methodology for this study.

GEOTHERMAL

Technology Status: Geothermal energy conversion from high-temperature (> 150°C) water dominated resource areas is a mature technology that has been commercially deployed since the 1960s. While research and development efforts are underway for advanced technology applications such as energy conversion from magma, these advances are not expected to be commercially viable by the year 2005. Such developing technologies are not considered in this study.

Cost and performance estimates in this study reflect conventional flash-plant technology. One such geothermal facility is currently operating on the Big Island in the Kilauea east rift zone. The potential geothermal projects included in this report represent additional 25 and 50 MW generation capacity installed near the existing facility. However, due to recent experience with public opposition to geothermal development in this area, it is expected that new geothermal development would require a lengthy permitting process before drilling and/or construction could be initiated. Therefore, the geothermal projects are presented as future technology (able to be installed by 2005).

Performance Assumptions: The Kilauea east rift zone is known to be a high-temperature hydrothermal resource area. This fact has been confirmed by recent assessment and project development activities. Performance estimate variations for conservative, nominal and optimistic cases accounts for the normal differences that are encountered between different production wells both in resource temperature and flow rate. Other factors that affect a plant's productivity are the efficiency losses associated with corrosivity, scaling, and equipment required to account for gas concentrations. The following basic assumptions were made:

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[8] Carmichael, A.D., E.E. Adams, and M.A. Glucksman. *Ocean Energy Technologies: The State of the Art*, Electric Power Research Institute, Palo Alto, California, EPRI AP-4921, 1986.

[9] Vega, L.A. "Economics of Ocean Thermal Energy Conversion (OTEC), in *Ocean Energy Recovery: The State of the Art*, edited by R.J. Seymour, American Society of Mechanical Engineers, New York, New York, 1992, pp. 152-181.

- The resource is a high temperature water dominated area. A normal amount of site and well variation is assumed relative to the experience of the existing power plant location.
- The exact plant configuration would depend on the resource condition, but is almost certain to include flashing, condensation, and reinjection.
- Energy losses include transmission losses, parasitic losses such as pumping, downtime, and equipment fouling.

Cost Basis: The following cost assumptions were made:

- Construction costs were based on the typical costs associated with similarly sized geothermal projects adjusted to account for Hawaii specific cost factors. The estimates assume that project construction management is handled appropriately to avoid any unnecessary overruns.
- Drilling costs include the assumption that some of the wells drilled will be non-productive. Even with the exploration performed for the existing facility, non-productive wells can be expected for any future expansions.
- Variations in the power plant costs account for potential variations in resource temperature, gas concentrations, corrosivity, and scaling characteristics.
- Permitting cost assumptions are consistent with the experience for similar geothermal projects and have been tailored specifically to development in Hawaii.

SECTION 3. RESOURCE SUPPLY CURVES

The Resource Supply Curve (RSC) computer model is an evaluation tool for use in comparing different energy generation options on each island and within the state. The model's database currently includes cost and performance information for over 230 potential renewable energy projects. In order to account for the optimistic, nominal, and conservative estimates, the database contains over 700 entries. The information in the database is used by the RSC program to calculate levelized cost of energy estimates in 1995 dollars for potential projects based on a set of criteria and economic assumptions selected by the user. Guidelines for using the model are included in Appendix A.

The model searches the database based on the chosen set of parameters and provides a graphical and tabular summary of the results of the query. The user can chose particular islands (or all islands), specific technologies (or all technologies), technology stage (current, future, or both), transmission cost (include, exclude, or both), certainty level (optimistic, nominal, conservative, or all), and project size ranges. The model is extremely flexible in that projects can be added or edited, and the majority of the economic parameters can be changed to represent different circumstances.

ECONOMIC ASSUMPTIONS

As previously discussed, the RSC model calculates levelized cost of energy in 1995 dollars based on the EPRI TAG methodology. The user has a choice of evaluating projects based on two valuation methods and two basic financing options. The valuation methods include constant dollar analysis (no inflation) or current dollar analysis. Financing options include either utility or non-utility financing. Default values are provided for each choice. For the utility financing options, the default values are those reported by HECO and HELCO in their Integrated Resource Plan submittals to the Hawaii Public Utility Commission. For non-utility financing, the default values are based on experience in obtaining financing for recent renewable energy independent power projects. To maximize the flexibility of the program, the user has the further option of changing the debt/equity ratios, the tax life, the inflation rate, the debt cost, the equity cost, the property tax, and the state and federal income tax to values other than the default values.

The cost of energy analysis also considers both state and federal tax credits and incentives. For each technology, both investment tax credits and production tax credits are included. The program assumes that the full value of the tax credits can be utilized. The user has the option of changing the default values or turning off the tax credits completely. A summary of the default settings for the economic variables is shown in Table 1.

RENEWABLE ENERGY PROJECTS INCLUDED IN THE DATABASE

Tables 2 through 5 list the potential renewable energy projects that are included in the database for each island. Additional information on the screening process to identify project sites and the characteristics of each project site are included in the Phase 1 report, *Renewable Energy Resource Assessment Plan.* Although no project sites are included in the database for either Lanai or Molokai, renewable energy has potential on these islands for use in small-scale applications. On these islands, the size of the utility grid, the extent of the existing renewable energy projects, and the projections for demand growth limit consideration of any additional utility-scale renewable energy projects at this time.

It should be noted that the list of projects included in the database is slightly different than those included in the Phase 1 report. In developing cost and project size estimates, several projects no longer appeared viable compared to other alternatives. In particular, several of the biomass projects were combined into larger projects and only representative combinations of crop types and project sites were evaluated to limit the size of the database. Other combinations may be viable. In addition, a few of the smaller hydroelectric projects were eliminated. A number of specific wave energy projects on each island have also been added to the database.

ILLUSTRATIVE RESOURCE SUPPLY CURVE RESULTS

Illustrative results from the resource supply curve program based on one possible set of economic parameters are shown in Appendix B. In the examples, only the most cost-effective project size is shown for each project site. An example is provided by island for all technologies (showing the most cost-effective projects at each project site on that island) and by technology for all islands (showing the most cost-effective projects at each project site within the state).

The illustrative results show that biomass projects using organic waste as a fuel source and wind energy projects are the least expensive options on each island. The biomass results are strongly dependent on the revenue that can be obtained from the tipping fees collected for waste disposal. Wind energy projects on each island are one of the lowest cost renewable energy alternatives under both current and future technology scenarios. Although only two hydroelectric projects were identified with significant development potential, current hydroelectric technology also offers one of the least-cost renewable energy options. For the technologies under development, cost and performance improvements in the future result in significantly lower cost-of-energy estimates in the future scenarios.

Appendix C includes the technology data worksheets with the supporting documentation for the cost and performance estimates. A separate worksheet showing optimistic, nominal, and conservative estimates is included for each project size and technology stage for all identified potential renewable energy projects. Each technology data sheet contains itemized cost and performance estimates that show the cost and performance assumptions that were were applied in this study.

Table 1. Resource Supply Curves Variable Summary

Program Settings and Options: 28-Sep-95

Financing Option:	Utility		**Valuation Option:**	Constant Dollars
Financing Variables	**Utility**	**Non-Utility**	**Valuation Variables**	
Debt Ratio	45%	70%	**Current Dollar:**	
Equity Ratio	55%	30%	Inflation	4.10%
			Discount Rate	10.14%
Debt Interest Rate	7.5%	9.0%	**Constant Dollar:**	
Equity Return Rate	12.3%	18.0%	Inflation	N/A
			Discount Rate	5.80%

Tax Credits	**Investment**			**Production**		
Technology	**State (%)**	**Federal (%)**	**Net (%)**	**State ($/kWh)**	**Federal ($/kWh)**	**Total ($/kWh)**
Wind	20.0%	0.0%	13.0%	$0.000	$0.010	$0.010
Solar Thermal	35.0%	10.0%	35.8%	$0.000	$0.000	$0.000
Photovoltaic	35.0%	10.0%	35.8%	$0.000	$0.000	$0.000
Biomass Fuel	0.0%	0.0%	0.0%	$0.000	$0.010	$0.010
Biomass Electric	0.0%	0.0%	0.0%	$0.000	$0.010	$0.010
Wave	0.0%	0.0%	0.0%	$0.000	$0.000	$0.000
OTEC	0.0%	0.0%	0.0%	$0.000	$0.000	$0.000
Hydro	0.0%	0.0%	0.0%	$0.000	$0.000	$0.000
Geothermal	0.0%	0.0%	0.0%	$0.000	$0.000	$0.000

Other Assumptions		
Tax Life	5	years
Property Tax & Insurance	2.00%	of annual expenses
State Income Tax	4.58%	of income
Federal Income Tax	35.00%	of income

Table 2. Hawaii Projects

Technology	Project Location	Size (MW)
Wind	Kahua Ranch	5, 15
	Lalamilo Wells	3, 30, 50
	N. Kohala	5, 15
Solar Thermal		
Dishes	Keahole	30
	N. Kohala	5, 15
	Waikoloa	30
Trough	Keahole	30
	Waikoloa	30
Photovoltaic		
Fixed	Keahole	30, 50
	N. Kohala	5, 15
	Waikoloa	30, 50
Tracking	Keahole	30, 50
	N. Kohala	5, 15
	Waikoloa	30, 50
Geothermal	Kilauea	25, 50
Biomass Electric		
Grass Crops	Hamakua Coast	25
	Hilo Coast	25
	Ka'u	25
Tree & Organic Waste	Hilo Coast	50
Tree Crops	Hamakua Coast	25
	Hilo Coast	25
Biomass Fuel-Methanol		
Grass Crops	Kaumakai	25 MGPY
Tree Crops	Hamakua Coast	25 MGPY
	Hilo Coast	25 MGPY
Hydro	Umauma Stream	13.8
Wave	Honokaa	10
	N. Kohala	10, 30
	Pepeekeo	10
Ocean Thermal	Keahole Point	60

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

Table 3. Maui Projects

Technology	Project Location	Size (MW)
Wind	McGregor Point	30
	N.W. Haleakala	10, 30, 50
	Puunene	10, 30
	West Maui	10, 30, 50
Solar Thermal		
Dishes	Kahului	10, 30
	Kihei	10, 30
	Puunene	10, 30
Trough	Kahului	30
	Kihei	30
	Puunene	30
Photovoltaic		
Fixed	Kahului	10, 30
	Kihei	10, 30
	Puunene	10, 30
Tracking	Kahului	10, 30
	Kihei	10, 30
	Puunene	10, 30
Biomass Electric		
Organic Waste	Paia-Puunene	25
Grass Crops	Paia-Puunene	25, 50
Tree Crops	Paia-Puunene	50
Biomass Fuel-Ethanol		
Grass Crops	Paia-Puunene	25, 50 MGPY
Tree Crops	Paia-Puunene	25 MGPY
Biomass Fuel-Methanol		
Organic Waste	Paia-Puunene	25 MGPY
Grass Crops	Paia-Puunene	50 MGPY
Tree Crops	Paia-Puunene	50 MGPY
Wave	Lower Paia	10, 30, 60
	Opana Point	10, 30, 60
	Waiehu Point	10, 30

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

Table 4. Oahu Projects

Technology	Project Location	Size (MW)
Wind	Kaena Point	2, 15
	Kahuku	30, 50, 80
Solar Thermal		
Dishes	Lualualei	50
	N. Ewa Plain	50
	Pearl Harbor	50
Trough	Lualualei	80
	N. Ewa Plain	80
	Pearl Harbor	80
Photovoltaic		
Fixed	Lualualei	10, 20, 50
	N. Ewa Plain	10, 50
	Pearl Harbor	10, 50
Tracking	Lualualei	10, 20, 50
	N. Ewa Plain	10, 50
	Pearl Harbor	10, 50
Biomass Electric		
Organic Waste	Barber's Point	50
Grass Crops	Waialua	25
Biomass Fuel		
Organic Waste-Ethanol	Barber's Point	25 MGPY
Organic Waste-Methanol	Barber's Point	50 MGPY
Wave	Makapuu	30, 60
	Mokapu Point	30
	N.E. Coast (upper)	30
	N.E. Coast (lower)	30
	Waimanalo	30
	Kahuku Point	30, 60
Ocean Thermal	Kahe Point	60

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

Table 5. Kauai Projects

Technology	Project Location	Size (MW)
Wind	Anahola	7
	N. Hanapepe	10
	Port Allen	5
Solar Thermal		
Dishes	Barking Sands	10
Photovoltaic		
Fixed	Barking Sands	10
Tracking	Barking Sands	10
Biomass Electric		
Grass Crops	Kaumakani	25
	Lihue	25
Tree & Organic Waste	Kaumakani	50
Tree Crops	Kaumakani	25
	Lihue	25
Biomass Fuel-Methanol		
Tree Crops	Kaumakani	25 MGPY
	Lihue	25 MGPY
Hydro	Wailua River	6.6
Wave	Anahola	10, 30
	Barking Sands	10, 30

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

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APPENDIX A

GUIDELINES FOR USING THE RSC COMPUTER MODEL

RSC program assistance will be provided at no cost for a period of one year. For assistance please contact Rana Vilhauer at RLA Consulting. Assistance is available by calling 206/488-0848 Monday through Friday from 8 AM to 4 PM (PST) or by fax by 206/488-0977. For additional assistance call DBED&T, Energy Division at 808/587-3800.

Hawaiian Renewable Energy Resource Supply Curve (RSC) Computer Model

INTRODUCTION

The purpose of the Resource Supply Curve (RSC) model is to provide the Department of Business, Economic Development & Tourism (DBED&T) with an evaluation tool for incorporating renewable energy into Hawaii's energy mix.

The RSC model was developed by R. Lynette & Associates, Inc. (RLA) under the Renewable Energy Assessment portion of the Hawaii Energy Strategy Program. RLA and affiliated subcontractors developed the database of potential renewable energy projects which is the foundation of the RSC model.

The results of the program are a graphical presentation of the cost of energy of each project versus the cumulative energy for all the projects meeting a specified criteria. Figure 1 is a sample of the graphical presentation and tabular summary which shows the potential projects that match a set of criteria selected by the user.

Following is a description of the menu-driven RSC model, the basis of the model, and its intended use. The RSC model and the economic assumptions is incorporates are based on the EPRI TAG methodology for calculating the levelized cost of energy for potential projects.

REQUIREMENTS

The model is intended to be used by DBED&T in its analysis of potential renewable energy projects in the State of Hawaii. The model is to be operated in QPro for Windows Version 5.0. The model was written on a 486 DX with 16 MB of RAM. Although the RSC model will run on a 386 computer, a 486 with at least 8 MB of RAM is recommended. The computer operator will be more comfortable with the model if they have some experience with Windows-based programs. The program is intended to be operated to a large degree with the use of a mouse.

INSTALLATION AND OPERATION

The RSC Model is a Quattro Pro for Windows file that makes use of Quattro Pro's spreadsheet, database, macro, and custom application capabilities. The model is executed by opening the file RSC_Ver4.WB1. The model is operated by selecting menu choices and dialogue box options. The main menu headings are RSC, variables, add, edit/delete, print/view, and quit. The following sections describe the operations available under each menu heading.

RSC

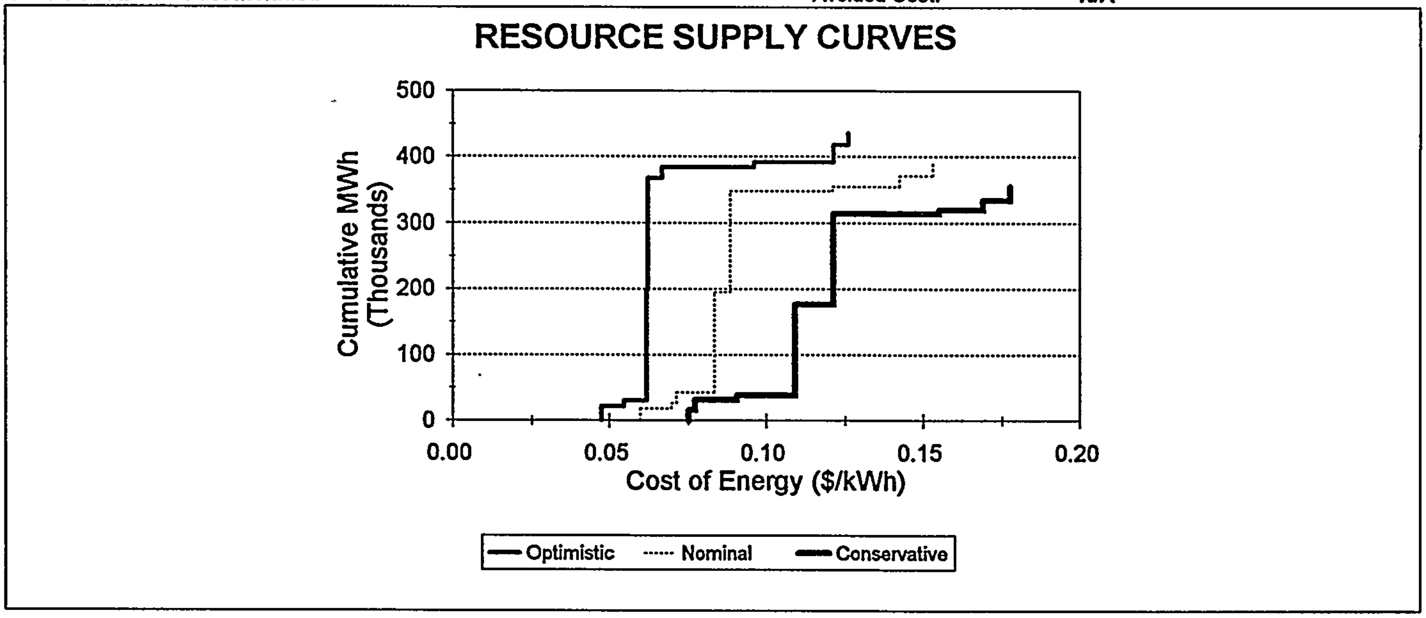
Choose this option to develop curves from the database of potential projects.

The RSC menu choice brings up a three-item secondary menu. The RSC process is begun by choosing to perform a New Query or going back to the Previous Query settings. You also have the option to Quit the program at this secondary menu level.

New Query

New Query provides the user choices of island, technology, technology stage, transmission cost, certainty level, and project size boundaries. These are the parameters by which the program will search the database.

Island(s):	**Kauai**	Valuation:	Constant Dollars
Technology:	**All Technologies**	Financing:	Utility
Stage:	**Current Technology**	Tax Credits:	Included
Certainty:	**Optimistic, Nominal, and Conservative**	Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	Avoided Cost:	N/A



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Current	Incl	Optimistic	10	1	30	21,296	0.0475
Wind		Kauai	Port Allen	Current	Incl	Optimistic	5	1	30	9,111	0.[illegible]
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Optimistic	25	2	30	168,630	0.0617
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Optimistic	25	2	30	168,630	0.0622
Hydro		Kauai	Wailua River	Current	Incl	Optimistic	6.6	2	50	16,770	0.0667
Wind		Kauai	Anahola	Current	Incl	Optimistic	7	1	30	7,800	0.0963
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Optimistic	10	2	30	25,483	0.1215
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Optimistic	10	1.5	30	17,250	0.1262
Wind		Kauai	N. Hanapepe	Current	Incl	Nominal	10	1	30	18,252	0.0598
Wind		Kauai	Port Allen	Current	Incl	Nominal	5	1	30	7,763	0.0696
Hydro		Kauai	Wailua River	Current	Incl	Nominal	6.6	2	50	16,435	0.0712
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Nominal	25	2	30	153,300	0.0834
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Nominal	25	2	30	153,300	0.0886
Wind		Kauai	Anahola	Current	Incl	Nominal	7	1	30	6,651	0.1210
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Nominal	10	1.5	30	16,428	0.1427
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Nominal	10	2	30	22,159	0.1533
Hydro		Kauai	Wailua River	Current	Incl	Conservative	6.6	2	50	16,267	0.0753
Wind		Kauai	N. Hanapepe	Current	Incl	Conservative	10	1	30	15,430	0.0774
Wind		Kauai	Port Allen	Current	Incl	Conservative	5	1	30	6,519	0.0909
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Conservative	25	2	30	137,970	0.1094
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Conservative	25	2	30	137,970	0.1215
Wind		Kauai	Anahola	Current	Incl	Conservative	7	1	30	5,589	0.1552
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Conservative	10	1.5	30	14,786	0.1691
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Conservative	10	2	30	19,943	0.1777

Figure 1

Figure 2 shows the Project Study dialog box which is displayed on the screen when the user choses "New Query." The use has the following options for defining the data query criteria.

- *Island* - one island, all islands, or combination of islands can be included.
- *Technology* - one, all, or any combination of the technologies may be included.
- *Technology Stage* - current, future, or a comparison of both (two lines are shown on the RSC graph).
- *Transmission Costs* - costs included in COE, excluded, or a comparison of both (two lines are shown on the RSC graph).
- *Certainty Level* - optimistic, nominal, conservative, or a comparison of all levels (three lines are shown on the RSC graph).
- *Installed Capacity* - any range of project size is allowed within the default setting of 0-999 MW.

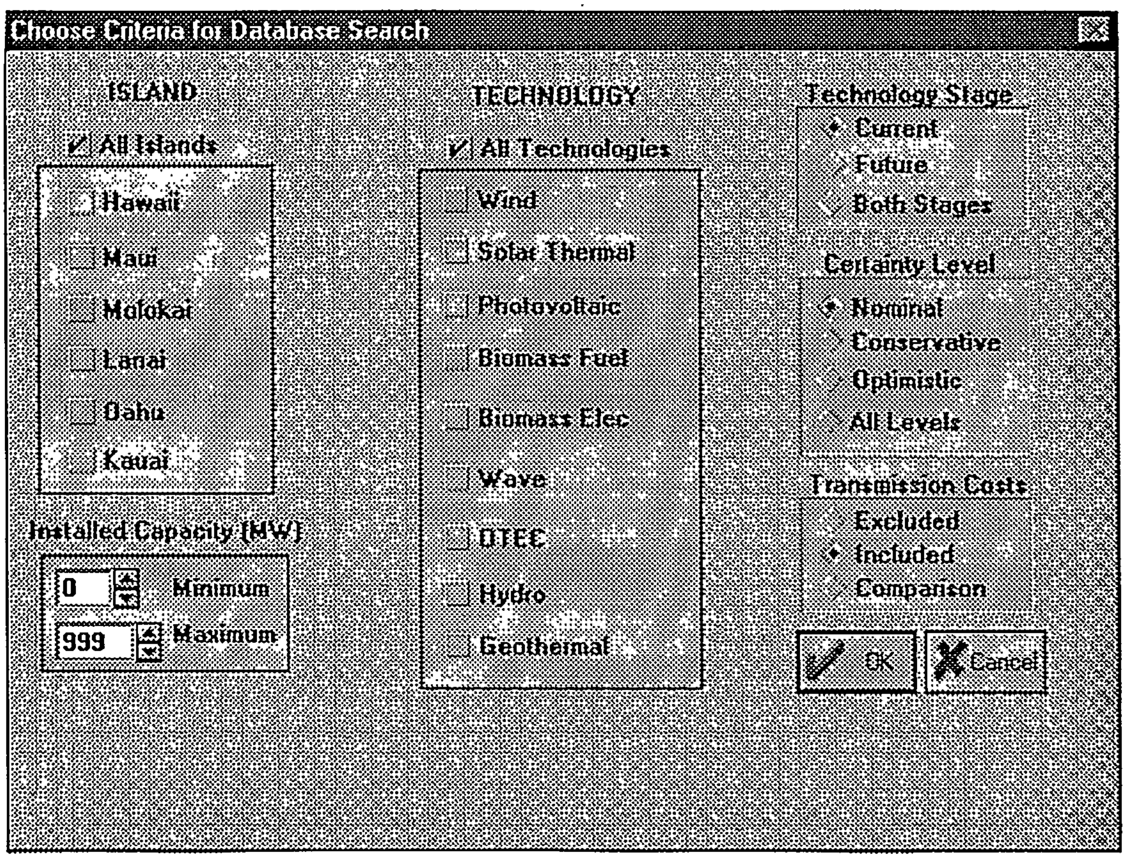


Figure 2

Graphing multiple comparisons within a single graph produces results that tend to be unclear. Multiple comparisons have been avoided by incorporating exclusions within the Project Study dialog box. For criteria settings for Technology Stage, Transmission Costs, and Certainty Level, if a multiple comparison has been chosen for one setting, multiple comparisons are excluded for the other two. For example, if the user chooses Both under Technology Stage, the options for Transmission Cost Comparison and All Levels of Certainty are "grayed" by the program and cannot be chosen.

when the user has defined the set of criteria and clicked on OK, the program will search the database to find records that meet the selected criteria.

The user is then prompted with a **Graphing Choice** to provide further search refinement. As shown in Figure 3, this prompt offers three possibilities.

- *Option 1* - Graph all projects found in the query.
- *Option 2* - Graph only the project with the lowest COE for each unique location (a single project is chosen for each location based on lowest COE). This option results in a short waiting period while the program sorts and eliminates extraneous data.
- *Option 3* - Allow for manually choosing the projects to graph from the data found in the query. This option allows the user to review the projects that met the criteria and manually eliminate unwanted projects.

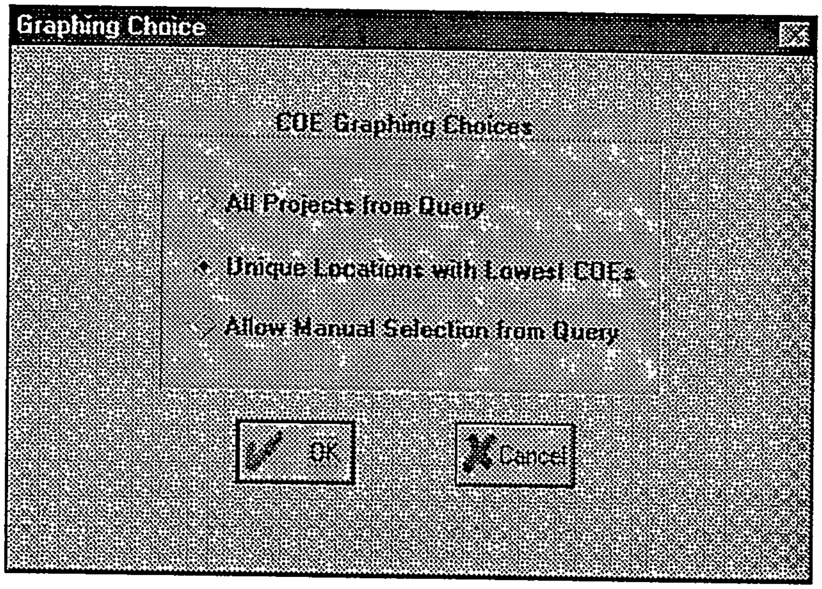


Figure 3

After the graphing choice is made, there is a waiting period and then the **Benchmarks** prompt is given. This prompt provides the option to include a benchmark COE value as a graphical comparison to the projects selected by the user's criteria settings. The benchmark is shown on the RSC graph as a single vertical line. Figure 4 shows the currently available benchmark options.

After the benchmark choice has been made, there is a short wait as the program processes the data. The length of the waiting period depends on the computer speed and the number of database records that met the search criteria. For example, choosing All Islands will require a longer waiting period than choosing only one island. The program is still processing if a "wait" or "macro" indicator appears in the lower right corner of the screen. When the calculations have been performed, the graph

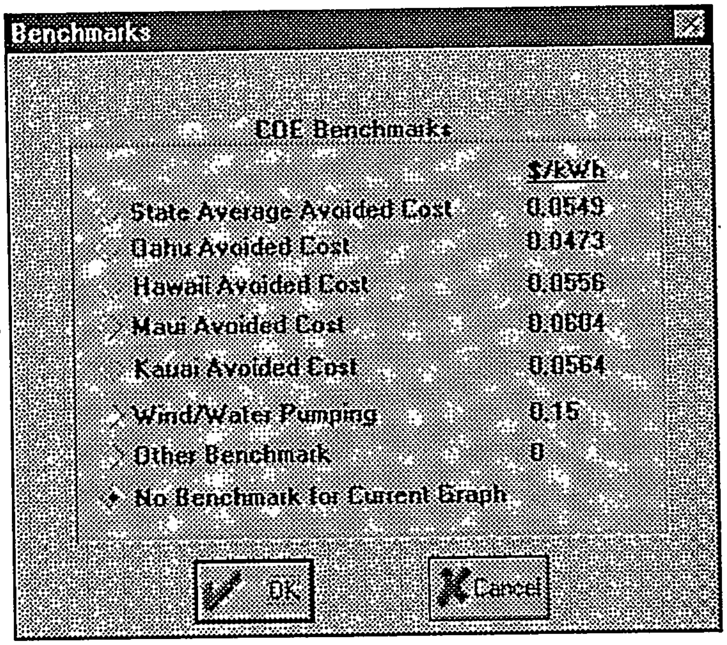


Figure 4

has been setup, and the data table assembled, the user will be prompted to choose between printing or viewing the results. The default setting is View. If the user chooses to view, they can later choose to print the current RSC graph and related data table from the main menu.

Previous Query

Previous Query begins with the criteria settings from the last query performed. This is useful for refining your criteria choices or performing similar queries. In all other ways, Previous Query provides the same choices and produces the same results as New Query.

Quit

Quit provides the opportunity to save (or not save) your changes, return QPro to its default settings, and exit the program.

VARIABLES

Choose this option to view or change the economic assumptions used in developing curves.

The Variables menu choice brings a four-item secondary menu that allows for changing, viewing and printing and current economic parameters, settings used in the program.

Choosing Calculation Method

User chooses the Valuation Method, either Constant or Current Dollar analysis; the Financing Option, either Utility or Non-Utility; and Tax Credits, either Included or Excluded. The discount rate, inflation rate, and debt equity ratio associated with these choices are shown. The dialog box, which is presented as Figure 5, also provides the user with a view of the current Economic Assumptions and Tax Credit settings.

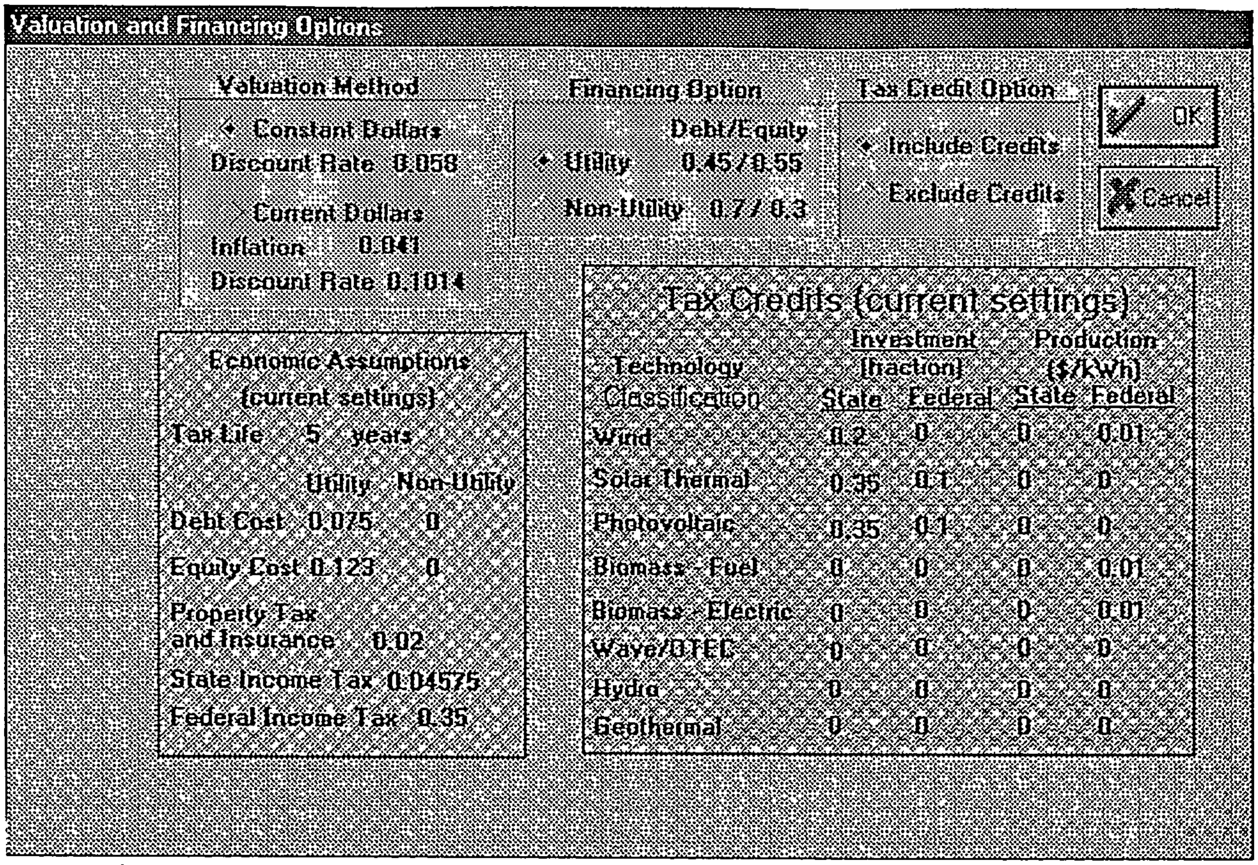


Figure 5

Change Economic Assumptions

The Economic Assumptions may be updated periodically, including the Financing Ratios and Tax Credits values, in the dialog box which is represented as Figure 6. It is advisable to have one person who is responsible for making required changes. Therefore, this option is password protected (Password = DBED). When leaving this dialog box with an **OK**, a macro is initiated that recalculates the Fixed Charge Rate tables.

Change COE Benchmarks

This option allows for updating the list of benchmarks and their related values. The Benchmarks dialog box with its current settings was shown previously in Figure 4.

Print Variables Summary

This option will send a summary of the variable settings to the printer.

ADD

Choose this option to add records to the database.

This option brings up the data entry form, shown in Figure 7, for entering new projects into the existing database. Information in the database was entered based on the Technology Data Sheets provided in Appendix C as documentation for the program. The Add Record entry form provides

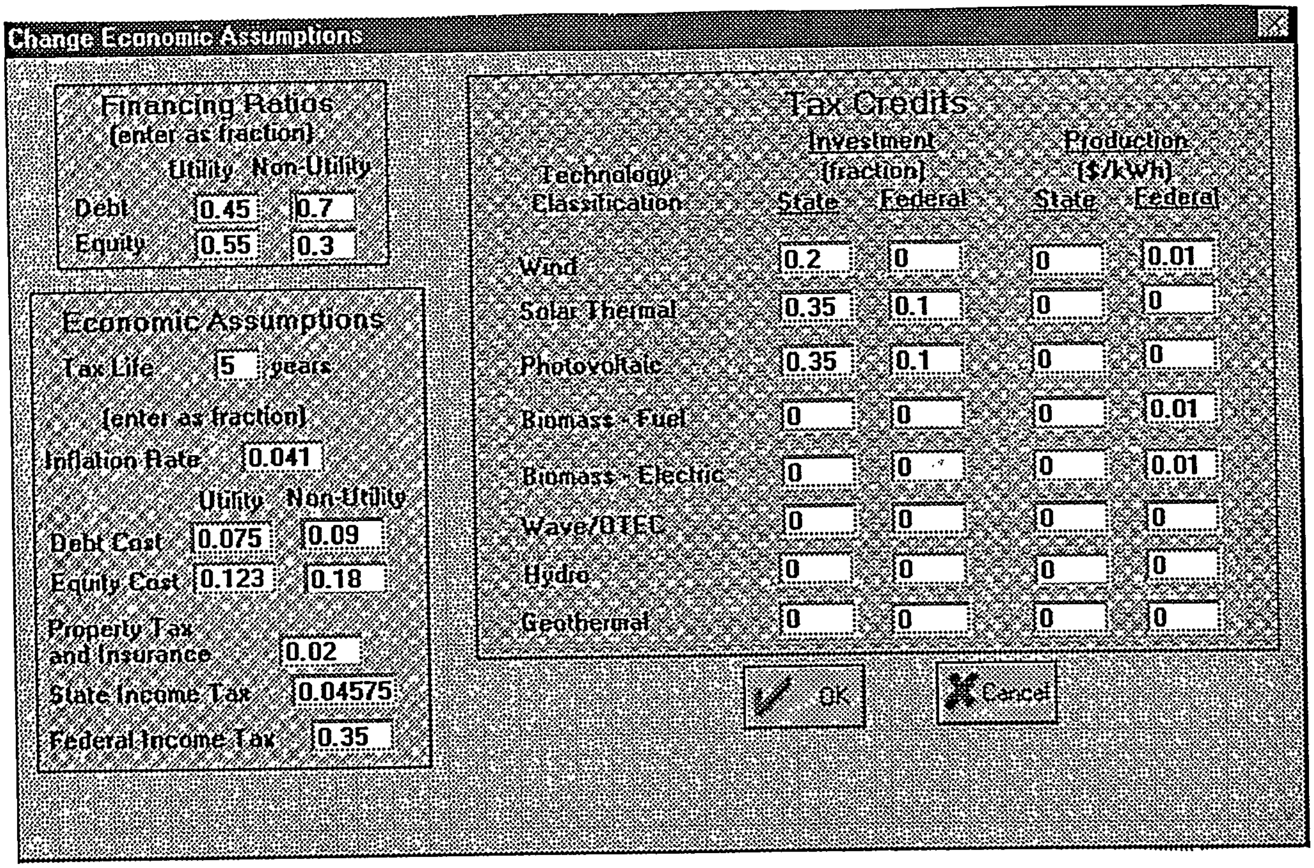


Figure 6

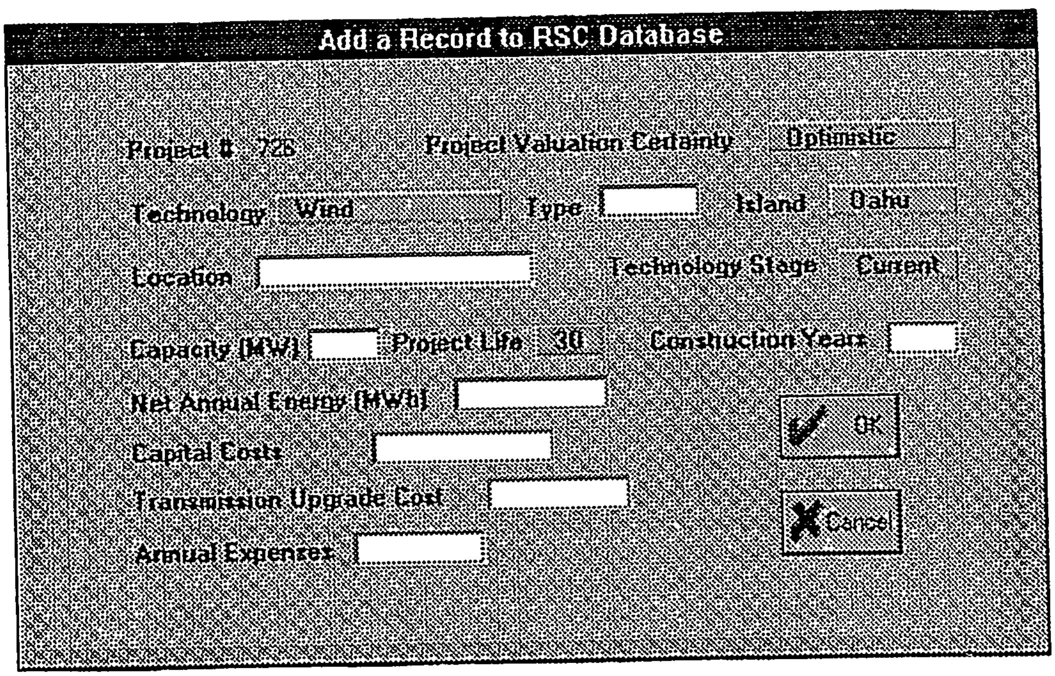


Figure 7

"pick lists" for several entry fields, which ensures that only acceptable field entry choices can be made. For example, there is a pick list for Technology which provides a list of all technology options currently available in the program. The user must choose one from the list.

Users are informed that the program requires project data records in multiples of three; Optimistic, Nominal and Conservative certainty levels. In most cases the user will also be entering project data records for Current and Future technology stages. It is recommended that a Technology Data Sheet be completed prior to adding a new project to the database. The data sheet can then be used to facilitate the addition of the record to the database.

EDIT/DELETE

Choose this option to edit or delete existing records in the database.

Editing and deleting data is accomplished by the use of a QPro Data Form, shown in Figure 8. This form is very flexible. Specific records can be easily found by using the Search option. Unwanted records can be permanently deleted from the database. It is, however, also very easy to accidentally make changes to the database in this form. Therefore, this option is password protected (password = DBED).

PRINT/VIEW

Choosing Print/View allows the user to view or print the most recently generated RSC graph and related data table.

QUIT

Quit provides the opportunity to save (or not save) your changes, return QPro to its default settings, and exit the program.

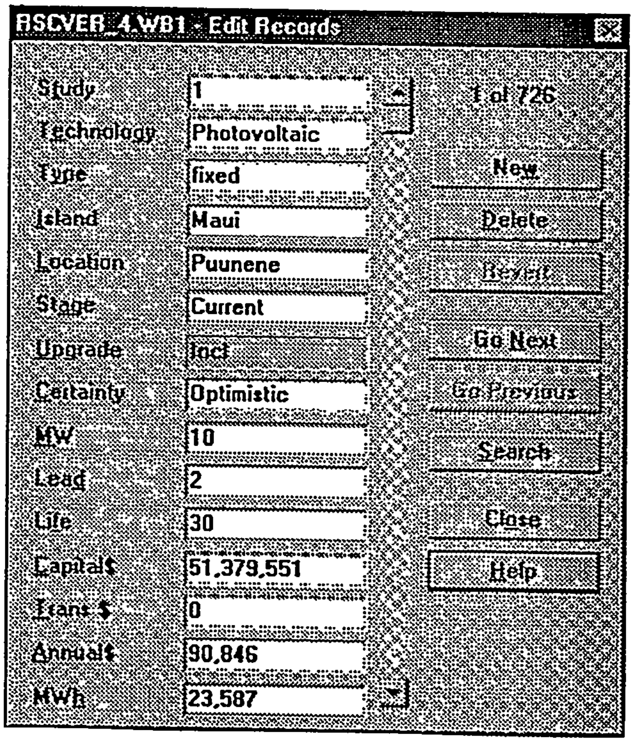


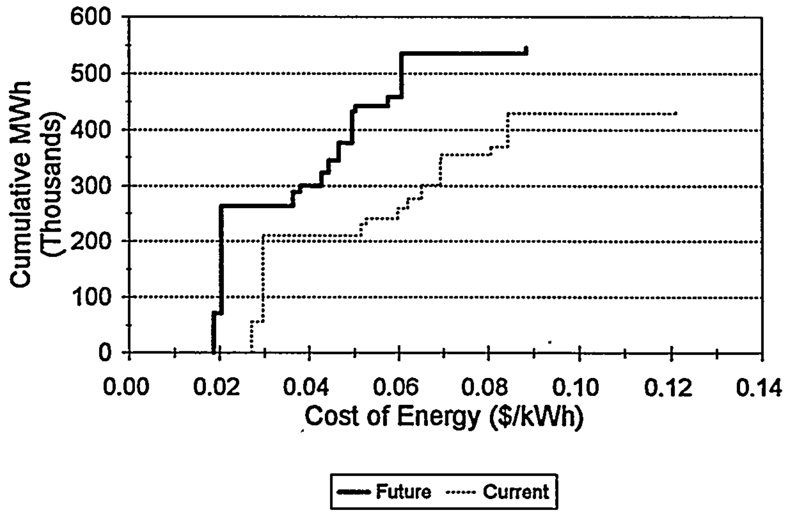
Figure 8

APPENDIX B

ILLUSTRATIVE RESULTS FROM THE RSC COMPUTER MODEL

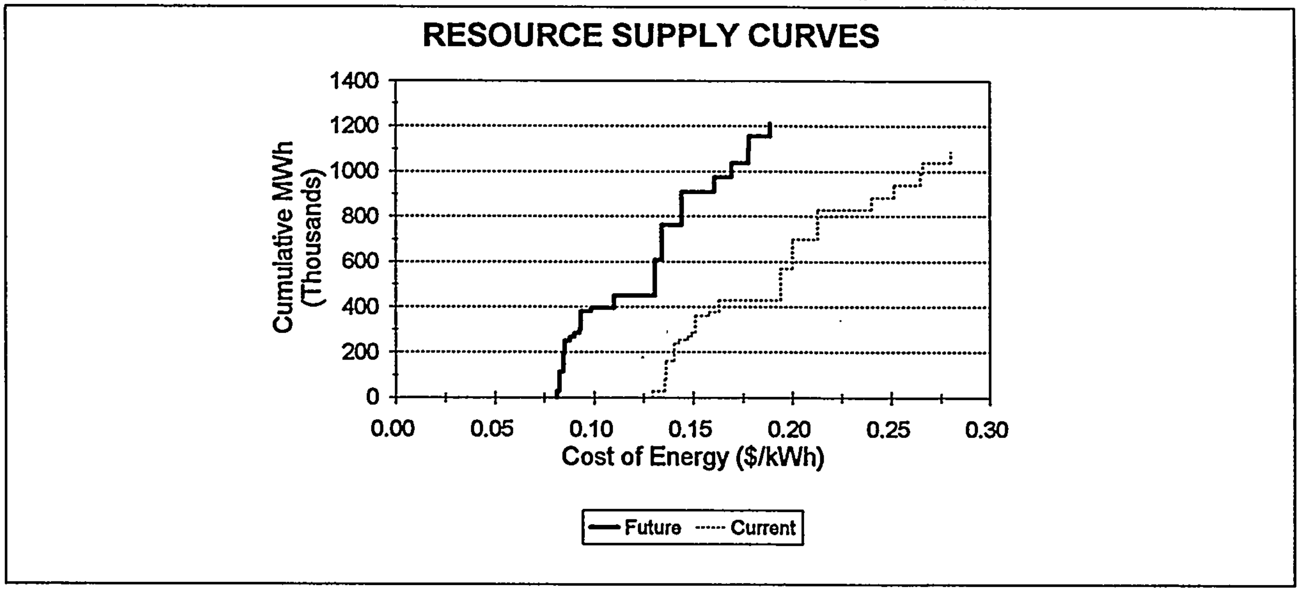
Island(s):	**All Islands**	Valuation:	Constant Dollars
Technology:	**Wind**	Financing:	Utility
Stage:	**Current and Future Technology**	Tax Credits:	Included
Certainty:	**Nominal**	Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	Avoided Cost:	N/A

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Nominal	15	1	30	71,178	0.0188
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	50	1	30	192,086	0.0204
Wind		Maui	McGregor Point	Future	Incl	Nominal	10	1	30	24,611	0.0365
Wind		Hawaii	Kahua Ranch	Future	Incl	Nominal	5	1	30	12,628	0.0380
Wind		Kauai	N. Hanapepe	Future	Incl	Nominal	10	1	30	22,602	0.0429
Wind		Maui	NW Haleakala	Future	Incl	Nominal	10	1	30	21,205	0.0445
Wind		Oahu	Kaena Point	Future	Incl	Nominal	15	1	30	31,558	0.0467
Wind		Oahu	Kahuku	Future	Incl	Nominal	30	1	30	56,977	0.0497
Wind		Kauai	Port Allen	Future	Incl	Nominal	5	1	30	9,321	0.0503
Wind		Maui	Puunene	Future	Incl	Nominal	10	1	30	15,784	0.0577
Wind		Maui	West Maui	Future	Incl	Nominal	50	1	30	77,546	0.0607
Wind		Kauai	Anahola	Future	Incl	Nominal	7	1	30	8,200	0.0884
Wind		Hawaii	North Kohala	Current	Incl	Nominal	15	1	30	56,905	0.0272
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	50	1	30	154,183	0.0297
Wind		Maui	McGregor Point	Current	Incl	Nominal	10	1	30	19,874	0.0515
Wind		Hawaii	Kahua Ranch	Current	Incl	Nominal	5	1	30	10,516	0.0527
Wind		Kauai	N. Hanapepe	Current	Incl	Nominal	10	1	30	18,252	0.0598
Wind		Maui	NW Haleakala	Current	Incl	Nominal	10	1	30	17,124	0.0620
Wind		Oahu	Kaena Point	Current	Incl	Nominal	15	1	30	25,230	0.0652
Wind		Oahu	Kahuku	Current	Incl	Nominal	30	1	30	45,551	0.0694
Wind		Kauai	Port Allen	Current	Incl	Nominal	5	1	30	7,763	0.0696
Wind		Maui	Puunene	Current	Incl	Nominal	10	1	30	12,746	0.0805
Wind		Maui	West Maui	Current	Incl	Nominal	50	1	30	62,245	0.0843
Wind		Kauai	Anahola	Current	Incl	Nominal	7	1	30	6,651	0.1210

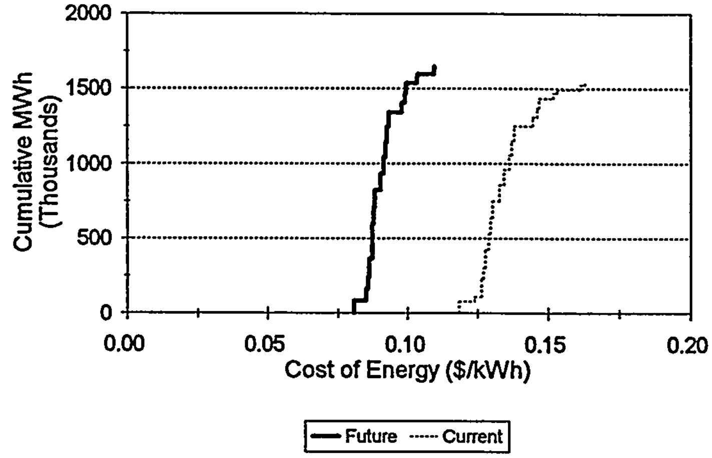
Island(s):	All Islands	Valuation:	Constant Dollars
Technology:	Solar_Thermal	Financing:	Utility
Stage:	Current and Future Technology	Tax Credits:	Included
Certainty:	Nominal	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	N/A



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	29,416	0.0814
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Nominal	50	1.5	30	84,949	0.0829
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Nominal	50	1.5	30	80,912	0.0846
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Nominal	30	1.5	30	55,125	0.0852
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Nominal	10	1.5	30	17,250	0.0878
Solar Thermal	dish	Maui	Puunene	Future	Incl	Nominal	10	1.5	30	16,430	0.0901
Solar Thermal	dish	Maui	Kihei	Future	Incl	Nominal	10	1.5	30	16,922	0.0929
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	1.5	30	78,489	0.0933
Solar Thermal	dish	Maui	Kahului	Future	Incl	Nominal	10	1.5	30	15,938	0.0984
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Nominal	30	1.5	30	53,674	0.1103
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Nominal	80	1.5	30	160,541	0.1307
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Nominal	80	1.5	30	152,911	0.1343
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Nominal	80	1.5	30	148,333	0.1443
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Nominal	30	1.5	30	64,499	0.1609
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Nominal	30	1.5	30	62,801	0.1694
Solar Thermal	trough	Maui	Puunene	Future	Incl	Nominal	30	1.5	30	57,092	0.1778
Solar Thermal	trough	Maui	Kihei	Future	Incl	Nominal	30	1.5	30	58,801	0.1781
Solar Thermal	trough	Maui	Kahului	Future	Incl	Nominal	30	1.5	30	55,382	0.1886
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Nominal	15	1.5	30	28,015	0.1294
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Nominal	30	1.5	30	52,500	0.1355
Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Nominal	50	1.5	30	80,904	0.1360
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Nominal	50	1.5	30	77,059	0.1403
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Nominal	10	1.5	30	16,428	0.1427
Solar Thermal	dish	Maui	Puunene	Current	Incl	Nominal	10	1.5	30	15,648	0.1474
Solar Thermal	dish	Maui	Kihei	Current	Incl	Nominal	10	1.5	30	16,116	0.1489
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	1.5	30	74,752	0.1509
Solar Thermal	dish	Maui	Kahului	Current	Incl	Nominal	10	1.5	30	15,179	0.1578
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Nominal	30	1.5	30	51,118	0.1629
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Nominal	80	1.5	30	139,601	0.1939
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Nominal	80	1.5	30	132,966	0.2001
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Nominal	80	1.5	30	128,985	0.2130
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Nominal	30	1.5	30	56,086	0.2402
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Nominal	30	1.5	30	54,610	0.2514
Solar Thermal	trough	Maui	Kihei	Current	Incl	Nominal	30	1.5	30	51,131	0.2646
Solar Thermal	trough	Maui	Puunene	Current	Incl	Nominal	30	1.5	30	49,645	0.2659
Solar Thermal	trough	Maui	Kahului	Current	Incl	Nominal	30	1.5	30	48,159	0.2803

Island(s):	All Islands	**Valuation:**	Constant Dollars
Technology:	Photovoltaic	**Financing:**	Utility
Stage:	Current and Future Technology	**Tax Credits:**	Included
Certainty:	Nominal	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	N/A

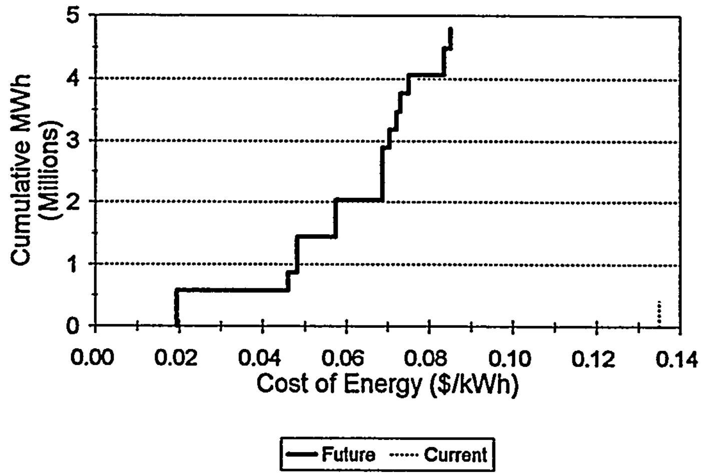
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Nominal	30	2	30	82,893	0.0807
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Nominal	30	2	30	77,792	0.0850
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Nominal	30	2	30	78,159	0.0857
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Nominal	50	3	30	124,319	0.0862
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Nominal	50	3	30	111,675	0.0873
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Nominal	50	3	30	124,319	0.0873
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Nominal	50	3	30	111,675	0.0878
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	3	30	111,675	0.0883
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Nominal	50	3	30	110,999	0.0903
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Nominal	50	3	30	110,999	0.0915
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Nominal	50	3	30	99,710	0.0921
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Nominal	50	3	30	99,710	0.0926
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	3	30	99,710	0.0932
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Nominal	30	2	30	63,764	0.0980
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Nominal	30	2	30	63,764	0.0992
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Nominal	30	2	30	63,544	0.0997
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	35,542	0.1035
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Nominal	10	1	30	22,962	0.1037
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	31,734	0.1096
Photovoltaic	fixed	Kauai	Barking Sands	Future	Incl	Nominal	10	1	30	20,502	0.1099
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Nominal	30	3	30	79,992	0.1186
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Nominal	10	2	30	28,158	0.1238
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Nominal	50	4	30	119,968	0.1264
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Nominal	30	3	30	75,069	0.1271
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Nominal	50	4	30	119,968	0.1278
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Nominal	50	4	30	107,766	0.1288
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Nominal	50	4	30	107,766	0.1297
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	4	30	107,766	0.1303
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Nominal	50	4	30	107,114	0.1328
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Nominal	50	4	30	107,114	0.1344
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Nominal	50	4	30	96,220	0.1364
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Nominal	50	4	30	96,220	0.1373
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	4	30	96,220	0.1381
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Nominal	30	3	30	61,532	0.1446
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Nominal	30	3	30	61,532	0.1462
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Nominal	30	3	30	61,320	0.1468
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Nominal	15	2.5	30	34,298	0.1519
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Nominal	10	2	30	22,159	0.1533
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Nominal	15	2.5	30	30,623	0.1614
Photovoltaic	fixed	Kauai	Barking Sands	Current	Incl	Nominal	10	2	30	19,785	0.1629

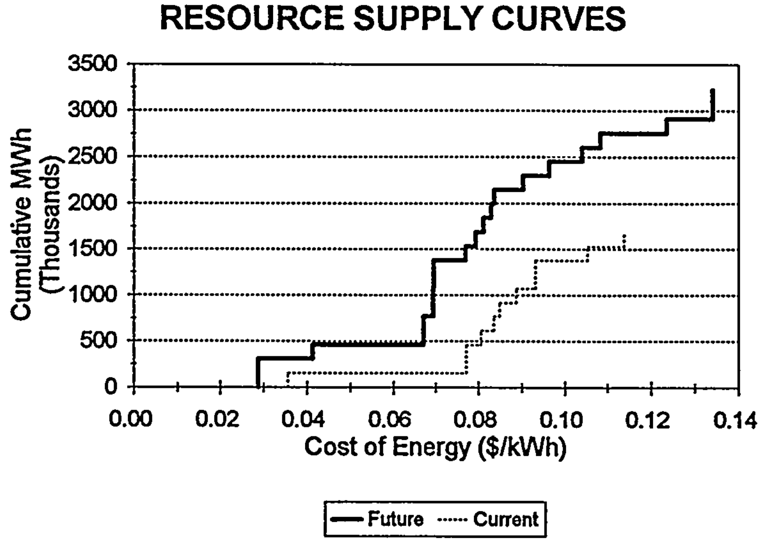
Island(s):	All Islands		Valuation:	Constant Dollars
Technology:	Biomass_Fuel		Financing:	Utility
Stage:	Current and Future Technology		Tax Credits:	Included
Certainty:	Nominal		Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included		Avoided Cost:	N/A

RESOURCE SUPPLY CURVES



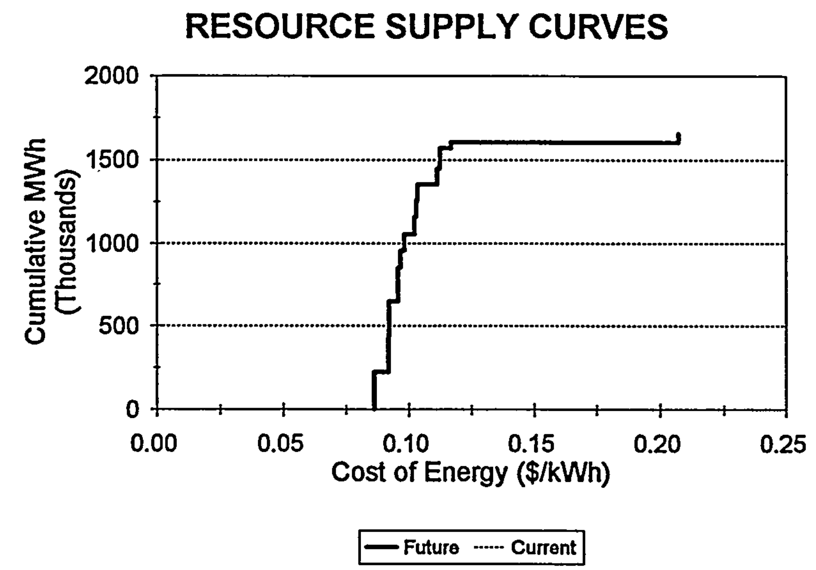
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Fuel	org waste-methanol	Oahu	Barber's Point	Future	Incl	Nominal	95	2	30	581,342	0.0195
Biomass Fuel	org waste-methanol	Maui	Puunene	Future	Incl	Nominal	47	2	30	290,671	0.0461
Biomass Fuel	tree crops-methanol	Maui	Paia-Puunene	Future	Incl	Nominal	95	2	30	581,342	0.0483
Biomass Fuel	grass crops-methanol	Maui	Paia-Puunene	Future	Incl	Nominal	95	2	30	581,342	0.0575
Biomass Fuel	grass crops-ethanol	Maui	Paia-Puunene	Future	Incl	Nominal	141	2	30	864,392	0.0688
Biomass Fuel	tree crops-methanol	Hawaii	Hamakua Coast	Future	Incl	Nominal	47	2	30	290,671	0.0705
Biomass Fuel	tree crops-methanol	Kauai	Lihue	Future	Incl	Nominal	47	2	30	290,671	0.0722
Biomass Fuel	tree crops-methanol	Hawaii	Hilo Coast	Future	Incl	Nominal	47	2	30	290,671	0.0731
Biomass Fuel	tree crops-methanol	Kauai	Kaumakani	Future	Incl	Nominal	47	2	30	290,671	0.0752
Biomass Fuel	tree crops-ethanol	Maui	Paia-Puunene	Future	Incl	Nominal	70	2	30	432,196	0.0835
Biomass Fuel	grass crops-methanol	Hawaii	Kaumakai	Future	Incl	Nominal	47	2	30	290,671	0.0850
Biomass Fuel	grass crops-ethanol	Maui	Paia-Puunene	Current	Incl	Nominal	70	2	30	432,196	0.1350

Island(s):	All Islands	Valuation:	Constant Dollars
Technology:	Biomass_Elec	Financing:	Utility
Stage:	Current and Future Technology	Tax Credits:	Included
Certainty:	Nominal	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	N/A



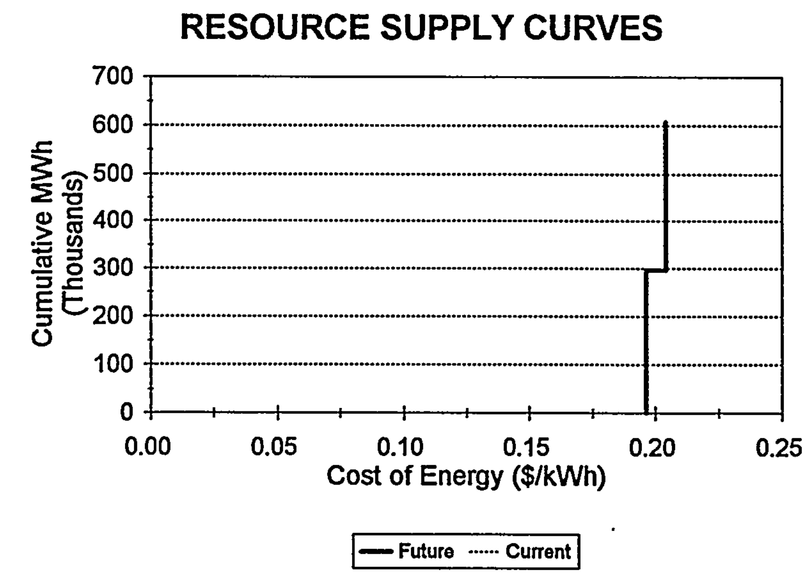
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Nominal	50	2	30	306,600	0.0289
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Nominal	25	2	30	153,300	0.0415
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Nominal	50	2	30	306,600	0.0672
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Nominal	50	2	30	306,600	0.0694
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	2	30	306,600	0.0695
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	2	30	153,300	0.0770
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Nominal	25	2	30	153,300	0.0794
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Nominal	25	2	30	153,300	0.0811
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Nominal	25	2	30	153,300	0.0829
Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Nominal	25	2	30	153,300	0.0837
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Nominal	25	2	30	153,300	0.0903
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	2	30	153,300	0.0964
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Nominal	25	2	30	153,300	0.1041
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Nominal	25	2	30	153,300	0.1083
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Nominal	25	2	30	153,300	0.1236
Biomass Elec	grass crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	2	30	306,600	0.1342
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Nominal	25	2	30	153,300	0.0357
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Nominal	50	2	30	306,600	0.0772
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Nominal	25	2	30	153,300	0.0805
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Nominal	25	2	30	153,300	0.0834
Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Nominal	25	2	30	153,300	0.0847
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Nominal	25	2	30	153,300	0.0886
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Nominal	50	2	30	306,600	0.0931
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Current	Incl	Nominal	25	2	30	153,300	0.1053
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Nominal	25	2	30	153,300	0.1139

Island(s):	**All Islands**	Valuation:	Constant Dollars
Technology:	**Wave**	Financing:	Utility
Stage:	**Current and Future Technology**	Tax Credits:	Included
Certainty:	**Nominal**	Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	Avoided Cost:	N/A



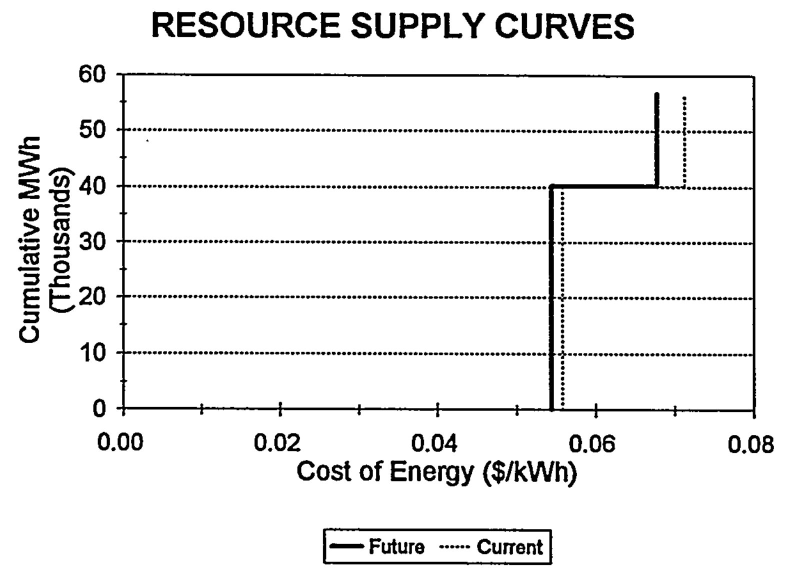
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wave		Oahu	Makapuu	Future	Incl	Nominal	60	2	30	224,378	0.0863
Wave		Oahu	Kahuku Point	Future	Incl	Nominal	60	2	30	211,197	0.0918
Wave		Maui	Opana Point	Future	Incl	Nominal	60	2	30	211,984	0.0920
Wave		Maui	Lower Paia	Future	Incl	Nominal	60	2	30	203,974	0.0956
Wave		Oahu	NE Coast 2A	Future	Incl	Nominal	30	2	30	103,704	0.0966
Wave		Oahu	NE Coast 2C	Future	Incl	Nominal	30	2	30	101,831	0.0982
Wave		Maui	Waiehu Point	Future	Incl	Nominal	30	2	30	101,256	0.1023
Wave		Kauai	Anahola	Future	Incl	Nominal	30	2	30	98,947	0.1030
Wave		Oahu	Mokapu Point	Future	Incl	Nominal	30	2	30	97,966	0.1034
Wave		Hawaii	N. Kohala	Future	Incl	Nominal	30	2	30	93,084	0.1112
Wave		Hawaii	Honokaa 2A	Future	Incl	Nominal	10	2	30	33,612	0.1125
Wave		Oahu	Waimanalo Bay	Future	Incl	Nominal	30	2	30	88,957	0.1128
Wave		Hawaii	Pepeekeo 2E	Future	Incl	Nominal	10	2	30	32,389	0.1171
Wave		Kauai	Barking Sands	Future	Incl	Nominal	30	2	30	51,793	0.2072

Island(s):	**All Islands**		Valuation:	Constant Dollars
Technology:	**OTEC**		Financing:	Utility
Stage:	**Current and Future Technology**		Tax Credits:	Included
Certainty:	**Nominal**		Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**		Avoided Cost:	N/A



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
OTEC		Hawaii	Keahole Point	Future	Incl	Nominal	60	2	30	296,438	0.1963
OTEC		Oahu	Kahe Point	Future	Incl	Nominal	60	2	30	311,260	0.2041

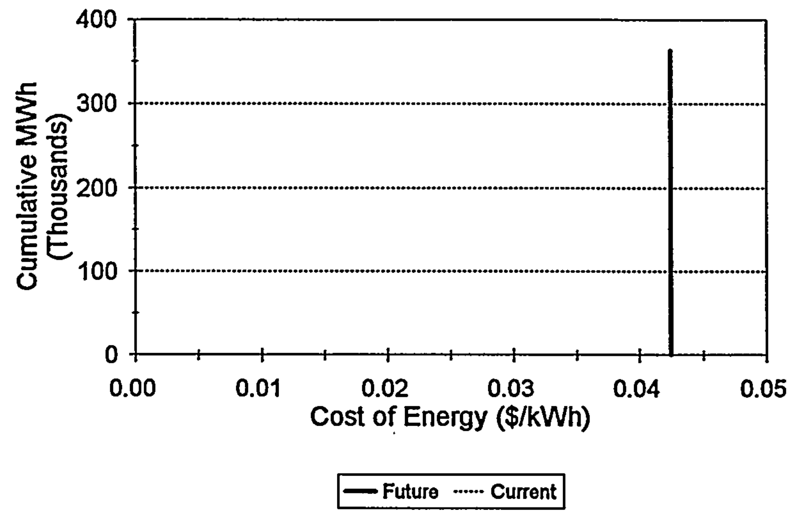
Island(s):	**All Islands**	Valuation:	Constant Dollars
Technology:	**Hydro**	Financing:	Utility
Stage:	**Current and Future Technology**	Tax Credits:	Included
Certainty:	**Nominal**	Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	Avoided Cost:	N/A



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Hydro		Hawaii	Umauma Stream	Future	Incl	Nominal	13.8	2	50	40,199	0.0544
Hydro		Kauai	Wailua River	Future	Incl	Nominal	6.6	2	50	16,435	0.0678
Hydro		Hawaii	Umauma Stream	Current	Incl	Nominal	13.8	2	50	40,199	0.0558
Hydro		Kauai	Wailua River	Current	Incl	Nominal	6.6	2	50	16,435	0.0712

Island(s):	**All Islands**	Valuation:	Constant Dollars
Technology:	**Geothermal**	Financing:	Utility
Stage:	**Current and Future Technology**	Tax Credits:	Included
Certainty:	**Nominal**	Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	Avoided Cost:	N/A

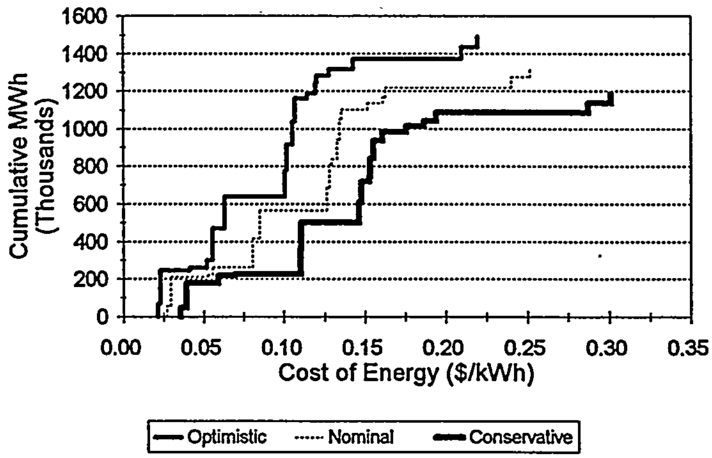
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Geothermal		Hawaii	Kilauea	Future	Incl -	Nominal	50	6	30	362,314	0.0425

Island(s):	Hawaii	Valuation:	Constant Dollars
Technology:	All Technologies	Financing:	Utility
Stage:	Current Technology	Tax Credits:	Included
Certainty:	Optimistic, Nominal, and Conservative	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	N/A

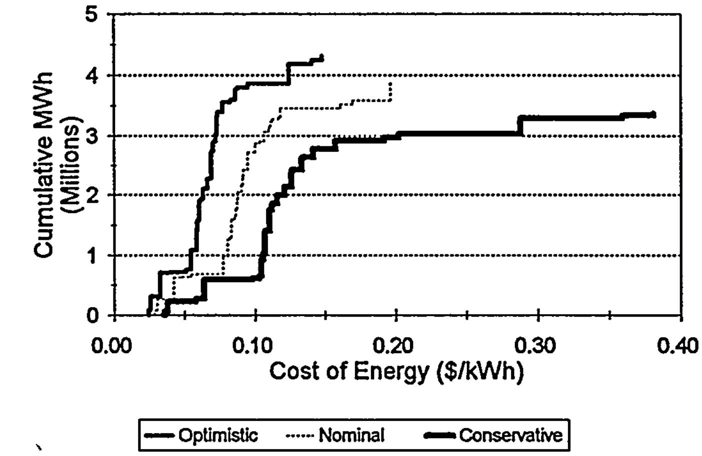
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Current	Incl	Optimistic	15	1	30	66,395	0.0215
Wind		Hawaii	Lalamilo Wells	Current	Incl	Optimistic	50	1	30	181,386	0.0233
Wind		Hawaii	Kahua Ranch	Current	Incl	Optimistic	5	1	30	12,334	0.0414
Hydro		Hawaii	Umauma Stream	Current	Incl	Optimistic	13.8	2	50	41,019	0.0522
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Optimistic	25	2	30	168,630	0.0558
Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Optimistic	25	2	30	168,630	0.0632
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Optimistic	50	4	30	137,963	0.1008
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Optimistic	50	4	30	137,963	0.1019
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Optimistic	50	4	30	123,181	0.1056
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Optimistic	50	4	30	123,181	0.1069
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Optimistic	15	1.5	30	29,416	0.1147
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Optimistic	30	1.5	30	55,125	0.1197
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Optimistic	15	2.5	30	39,442	0.1207
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Optimistic	15	2.5	30	35,216	0.1281
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Optimistic	30	1.5	30	53,674	0.1433
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Optimistic	30	1.5	30	58,890	0.2102
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Optimistic	30	1.5	30	57,340	0.2199
Wind		Hawaii	North Kohala	Current	Incl	Nominal	15	1	30	56,905	0.0272
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	50	1	30	154,183	0.0297
Wind		Hawaii	Kahua Ranch	Current	Incl	Nominal	5	1	30	10,516	0.0527
Hydro		Hawaii	Umauma Stream	Current	Incl	Nominal	13.8	2	50	40,199	0.0558
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Nominal	25	2	30	153,300	0.0805
Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Nominal	25	2	30	153,300	0.0847
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Nominal	50	4	30	119,968	0.1264
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Nominal	50	4	30	119,968	0.1278
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Nominal	15	1.5	30	28,015	0.1294
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Nominal	50	4	30	107,114	0.1328
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Nominal	50	4	30	107,114	0.1344
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Nominal	30	1.5	30	52,500	0.1355
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Nominal	15	2.5	30	34,298	0.1519
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Nominal	15	2.5	30	30,623	0.1614
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Nominal	30	1.5	30	51,118	0.1629
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Nominal	30	1.5	30	56,086	0.2402
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Nominal	30	1.5	30	54,610	0.2514
Wind		Hawaii	North Kohala	Current	Incl	Conservative	15	1	30	48,105	0.0360
Wind		Hawaii	Lalamilo Wells	Current	Incl	Conservative	50	1	30	129,123	0.0396
Hydro		Hawaii	Umauma Stream	Current	Incl	Conservative	13.8	2	50	39,788	0.0591
Wind		Hawaii	Kahua Ranch	Current	Incl	Conservative	5	1	30	8,838	0.0691
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Conservative	25	2	30	137,970	0.1107

Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Conservative	25	2	30	137,970	0.1111
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Conservative	50	4	30	107,971	0.1466
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Conservative	50	4	30	107,971	0.1483
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Conservative	15	1.5	30	25,213	0.1532
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Conservative	50	4	30	96,402	0.1539
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Conservative	50	4	30	96,402	0.1558
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Conservative	30	1.5	30	47,250	0.1612
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Conservative	15	2.5	30	30,868	0.1760
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Conservative	15	2.5	30	27,561	0.1869
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Conservative	30	1.5	30	46,006	0.1946
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Conservative	30	1.5	30	50,477	0.2878
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Conservative	30	1.5	30	49,149	0.3014

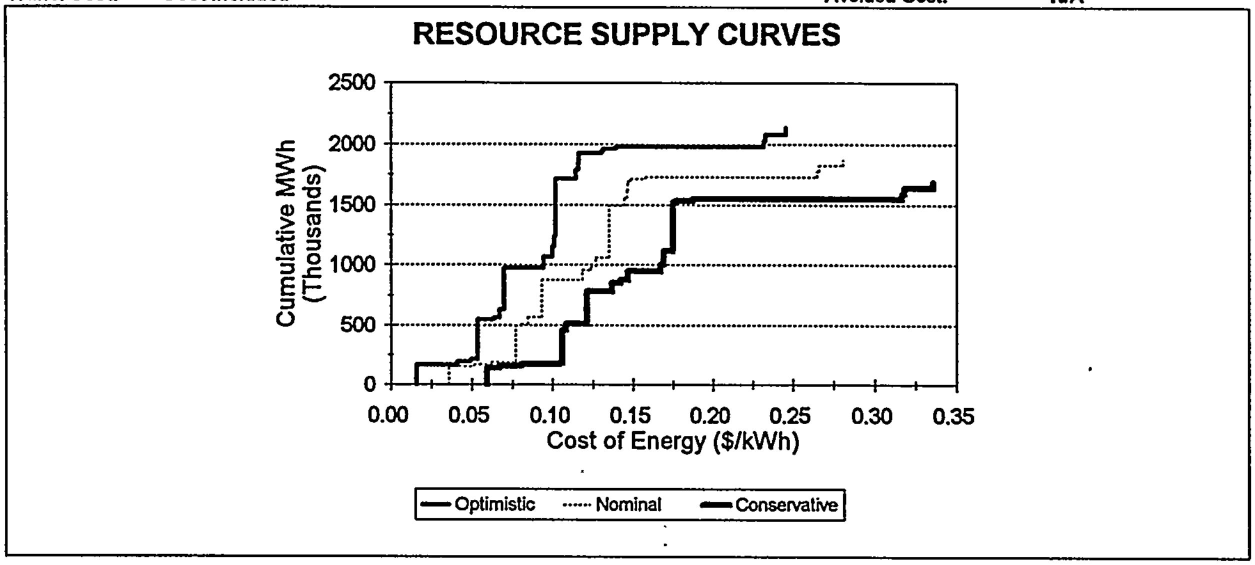
Island(s):	**Hawaii**	**Valuation:**	**Constant Dollars**
Technology:	**All Technologies**	**Financing:**	**Utility**
Stage:	**Future Technology**	**Tax Credits:**	**Included**
Certainty:	**Optimistic, Nominal, and Conservative**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**N/A**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Optimistic	15	1	30	83,049	0.0247
Wind		Hawaii	Lalamilo Wells	Future	Incl	Optimistic	50	1	30	225,977	0.0258
Geothermal		Hawaii	Kilauea	Future	Incl	Optimistic	50	6	30	390,871	0.0328
Wind		Hawaii	Kahua Ranch	Future	Incl	Optimistic	5	1	30	14,811	0.0397
Hydro		Hawaii	Umauma Stream	Future	Incl	Optimistic	13.8	2	50	41,019	0.0509
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Optimistic	50	2	30	337,260	0.0546
Biomass Fuel	tree crops-methanol	Hawaii	Hamakua Coast	Future	Incl	Optimistic	47	2	30	319,738	0.0586
Wave		Hawaii	Honokaa 2A	Future	Incl	Optimistic	10	2	30	42,134	0.0591
Wave		Hawaii	N. Kohala	Future	Incl	Optimistic	30	2	30	117,856	0.0592
Biomass Fuel	tree crops-methanol	Hawaii	Hilo Coast	Future	Incl	Optimistic	47	2	30	319,738	0.0605
Wave		Hawaii	Pepeekeo 2E	Future	Incl	Optimistic	10	2	30	40,968	0.0610
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0633
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0663
Biomass Fuel	grass crops-methanol	Hawaii	Kaumakai	Future	Incl	Optimistic	47	2	30	319,738	0.0691
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Optimistic	50	3	30	142,967	0.0692
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Optimistic	50	3	30	142,967	0.0701
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Optimistic	15	1.5	30	30,886	0.0709
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Optimistic	50	3	30	127,649	0.0723
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Optimistic	25	2	30	168,630	0.0729
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Optimistic	50	3	30	127,649	0.0733
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Optimistic	30	1.5	30	57,882	0.0738
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0774
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Optimistic	15	1.5	30	40,873	0.0828
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0861
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Optimistic	15	1.5	30	36,494	0.0876
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Optimistic	30	1.5	30	56,358	0.0953
OTEC		Hawaii	Keahole Point	Future	Incl	Optimistic	60	2	30	319,565	0.1249
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Optimistic	30	1.5	30	67,724	0.1411
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Optimistic	30	1.5	30	65,941	0.1483
Wind		Hawaii	North Kohala	Future	Incl	Nominal	15	1	30	71,178	0.0288
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	50	1	30	192,086	0.0304
Geothermal		Hawaii	Kilauea	Future	Incl	Nominal	50	6	30	362,314	0.0425
Wind		Hawaii	Kahua Ranch	Future	Incl	Nominal	5	1	30	12,628	0.0480
Hydro		Hawaii	Umauma Stream	Future	Incl	Nominal	13.8	2	50	40,199	0.0544
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Nominal	50	2	30	306,600	0.0772
Biomass Fuel	tree crops-methanol	Hawaii	Hamakua Coast	Future	Incl	Nominal	47	2	30	290,671	0.0805
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	29,416	0.0814
Biomass Fuel	tree crops-methanol	Hawaii	Hilo Coast	Future	Incl	Nominal	47	2	30	290,671	0.0831
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Nominal	30	1.5	30	55,125	0.0852

Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Nominal	50	3	30	124,319	0.0862
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	2	30	153,300	0.0870
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Nominal	50	3	30	124,319	0.0873
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Nominal	50	3	30	110,999	0.0903
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Nominal	25	2	30	153,300	0.0911
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Nominal	50	3	30	110,999	0.0915
Biomass Fuel	grass crops-methanol	Hawaii	Kaumakai	Future	Incl	Nominal	47	2	30	290,671	0.0950
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Nominal	25	2	30	153,300	0.1003
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	35,542	0.1035
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	2	30	153,300	0.1064
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	31,734	0.1096
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Nominal	30	1.5	30	53,674	0.1103
Wave		Hawaii	N. Kohala	Future	Incl	Nominal	30	2	30	93,084	0.1112
Wave		Hawaii	Honokaa 2A	Future	Incl	Nominal	10	2	30	33,612	0.1125
Wave		Hawaii	Pepeekeo 2E	Future	Incl	Nominal	10	2	30	32,389	0.1171
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Nominal	25	2	30	153,300	0.1183
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Nominal	30	1.5	30	64,499	0.1609
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Nominal	30	1.5	30	62,801	0.1694
OTEC		Hawaii	Keahole Point	Future	Incl	Nominal	60	2	30	296,438	0.1963
Wind		Hawaii	North Kohala	Future	Incl	Conservative	15	1	30	60,171	0.0360
Wind		Hawaii	Lalamilo Wells	Future	Incl	Conservative	50	1	30	160,865	0.0385
Hydro		Hawaii	Umauma Stream	Future	Incl	Conservative	13.8	2	50	39,788	0.0576
Wind		Hawaii	Kahua Ranch	Future	Incl	Conservative	5	1	30	10,612	0.0617
Geothermal		Hawaii	Kilauea	Future	Incl	Conservative	50	6	30	308,352	0.0641
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Conservative	15	1.5	30	26,474	0.0978
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Conservative	30	1.5	30	49,613	0.1031
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Conservative	50	2	30	275,940	0.1049
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Conservative	50	3	30	105,671	0.1060
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Conservative	50	3	30	105,671	0.1073
Biomass Fuel	tree crops-methanol	Hawaii	Hamakua Coast	Future	Incl	Conservative	47	2	30	261,604	0.1073
Biomass Fuel	tree crops-methanol	Hawaii	Hilo Coast	Future	Incl	Conservative	47	2	30	261,604	0.1108
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Conservative	50	3	30	94,349	0.1109
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Conservative	50	3	30	94,349	0.1124
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Conservative	25	2	30	137,970	0.1160
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Conservative	25	2	30	137,970	0.1215
Biomass Fuel	grass crops-methanol	Hawaii	Kaumakai	Future	Incl	Conservative	47	2	30	261,604	0.1267
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Conservative	15	1.5	30	30,211	0.1270
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Conservative	30	1.5	30	48,307	0.1337
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Conservative	25	2	30	137,970	0.1337
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Conservative	15	1.5	30	26,974	0.1344
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Conservative	25	2	30	137,970	0.1419
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Conservative	25	2	30	137,970	0.1578
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Conservative	30	1.5	30	58,049	0.1922
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Conservative	30	1.5	30	56,521	0.2025
OTEC		Hawaii	Keahole Point	Future	Incl	Conservative	60	2	30	257,894	0.2887
Wave		Hawaii	N. Kohala	Future	Incl	Conservative	30	2	30	42,077	0.3596
Wave		Hawaii	Honokaa 2A	Future	Incl	Conservative	10	2	30	15,435	0.3619
Wave		Hawaii	Pepeekeo 2E	Future	Incl	Conservative	10	2	30	14,691	0.3811

Island(s):	**Maui**	**Valuation:**	**Constant Dollars**
Technology:	**All Technologies**	**Financing:**	**Utility**
Stage:	**Current Technology**	**Tax Credits:**	**Included**
Certainty:	**Optimistic, Nominal, and Conservative**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**N/A**

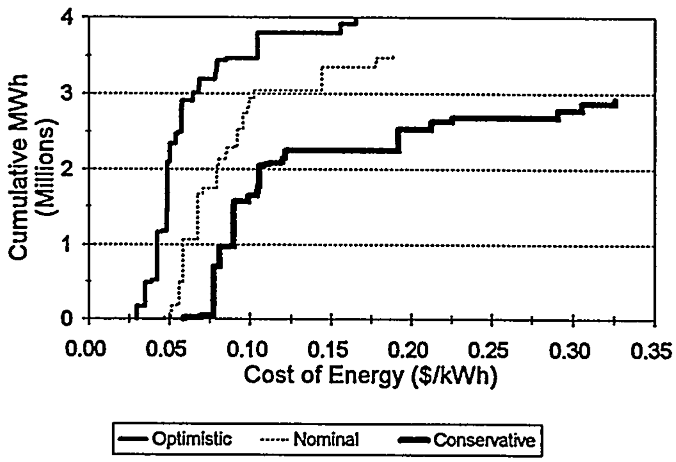


Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Optimistic	25	2	30	168,630	0.0160
Wind		Maui	McGregor Point	Current	Incl	Optimistic	10	1	30	23,189	0.0408
Wind		Maui	NW Haleakala	Current	Incl	Optimistic	10	1	30	19,980	0.0492
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Optimistic	50	2	30	337,260	0.0534
Wind		Maui	Puunene	Current	Incl	Optimistic	10	1	30	14,940	0.0636
Wind		Maui	West Maui	Current	Incl	Optimistic	50	1	30	72,957	0.0670
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Optimistic	50	2	30	337,260	0.0697
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Optimistic	30	3	30	91,990	0.0944
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Optimistic	30	3	30	86,737	0.1002
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Optimistic	30	3	30	86,330	0.1012
Biomass Fuel	grass crops-ethanol	Maui	Paia-Puunene	Current	Incl	Optimistic	70	2	30	475,416	0.1020
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Optimistic	30	3	30	70,762	0.1149
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Optimistic	30	3	30	70,762	0.1162
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Optimistic	30	3	30	70,518	0.1167
Solar Thermal	dish	Maui	Puunene	Current	Incl	Optimistic	10	1.5	30	16,430	0.1305
Solar Thermal	dish	Maui	Kihei	Current	Incl	Optimistic	10	1.5	30	16,922	0.1316
Solar Thermal	dish	Maui	Kahului	Current	Incl	Optimistic	10	1.5	30	15,938	0.1395
Solar Thermal	trough	Maui	Kihei	Current	Incl	Optimistic	30	1.5	30	53,688	0.2318
Solar Thermal	trough	Maui	Puunene	Current	Incl	Optimistic	30	1.5	30	52,127	0.2330
Solar Thermal	trough	Maui	Kahului	Current	Incl	Optimistic	30	1.5	30	50,567	0.2454
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Nominal	25	2	30	153,300	0.0357
Wind		Maui	McGregor Point	Current	Incl	Nominal	10	1	30	19,874	0.0515
Wind		Maui	NW Haleakala	Current	Incl	Nominal	10	1	30	17,124	0.0620
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Nominal	50	2	30	306,600	0.0772
Wind		Maui	Puunene	Current	Incl	Nominal	10	1	30	12,746	0.0805
Wind		Maui	West Maui	Current	Incl	Nominal	50	1	30	62,245	0.0843
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Nominal	50	2	30	306,600	0.0931
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Nominal	30	3	30	79,992	0.1186
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Nominal	10	2	30	28,158	0.1238
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Nominal	30	3	30	75,069	0.1271
Biomass Fuel	grass crops-ethanol	Maui	Paia-Puunene	Current	Incl	Nominal	70	2	30	432,196	0.1350
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Nominal	30	3	30	61,532	0.1446
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Nominal	30	3	30	61,532	0.1462
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Nominal	30	3	30	61,320	0.1468
Solar Thermal	dish	Maui	Puunene	Current	Incl	Nominal	10	1.5	30	15,648	0.1474
Solar Thermal	dish	Maui	Kihei	Current	Incl	Nominal	10	1.5	30	16,116	0.1489
Solar Thermal	dish	Maui	Kahului	Current	Incl	Nominal	10	1.5	30	15,179	0.1578
Solar Thermal	trough	Maui	Kihei	Current	Incl	Nominal	30	1.5	30	51,131	0.2646
Solar Thermal	trough	Maui	Puunene	Current	Incl	Nominal	30	1.5	30	49,645	0.2659

Solar Thermal	trough	Maui	Kahului	Current	Incl	Nominal	30	1.5	30	48,159	0.2803
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Conservative	25	2	30	137,970	0.0597
Wind		Maui	McGregor Point	Current	Incl	Conservative	10	1	30	16,801	0.0669
Wind		Maui	NW Haleakala	Current	Incl	Conservative	10	1	30	14,476	0.0803
Wind		Maui	Puunene	Current	Incl	Conservative	10	1	30	10,720	0.1043
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Conservative	50	2	30	275,940	0.1063
Wind		Maui	West Maui	Current	Incl	Conservative	50	1	30	52,349	0.1085
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Conservative	50	2	30	275,940	0.1218
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Conservative	30	3	30	71,992	0.1372
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Conservative	10	2	30	25,343	0.1424
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Conservative	30	3	30	67,562	0.1471
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Conservative	30	3	30	55,379	0.1672
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Conservative	30	3	30	55,379	0.1692
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Conservative	30	3	30	55,188	0.1698
Solar Thermal	dish	Maui	Puunene	Current	Incl	Conservative	10	1.5	30	14,083	0.1748
Biomass Fuel	grass crops-ethanol	Maui	Paia-Puunene	Current	Incl	Conservative	70	2	30	388,977	0.1753
Solar Thermal	dish	Maui	Kihei	Current	Incl	Conservative	10	1.5	30	14,505	0.1767
Solar Thermal	dish	Maui	Kahului	Current	Incl	Conservative	10	1.5	30	13,661	0.1874
Solar Thermal	trough	Maui	Kihei	Current	Incl	Conservative	30	1.5	30	46,018	0.3169
Solar Thermal	trough	Maui	Puunene	Current	Incl	Conservative	30	1.5	30	44,681	0.3184
Solar Thermal	trough	Maui	Kahului	Current	Incl	Conservative	30	1.5	30	43,343	0.3358

Island(s):	**Maui**	**Valuation:**	**Constant Dollars**
Technology:	**All Technologies**	**Financing:**	**Utility**
Stage:	**Future Technology**	**Tax Credits:**	**Included**
Certainty:	**Optimistic, Nominal, and Conservative**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**N/A**

RESOURCE SUPPLY CURVES

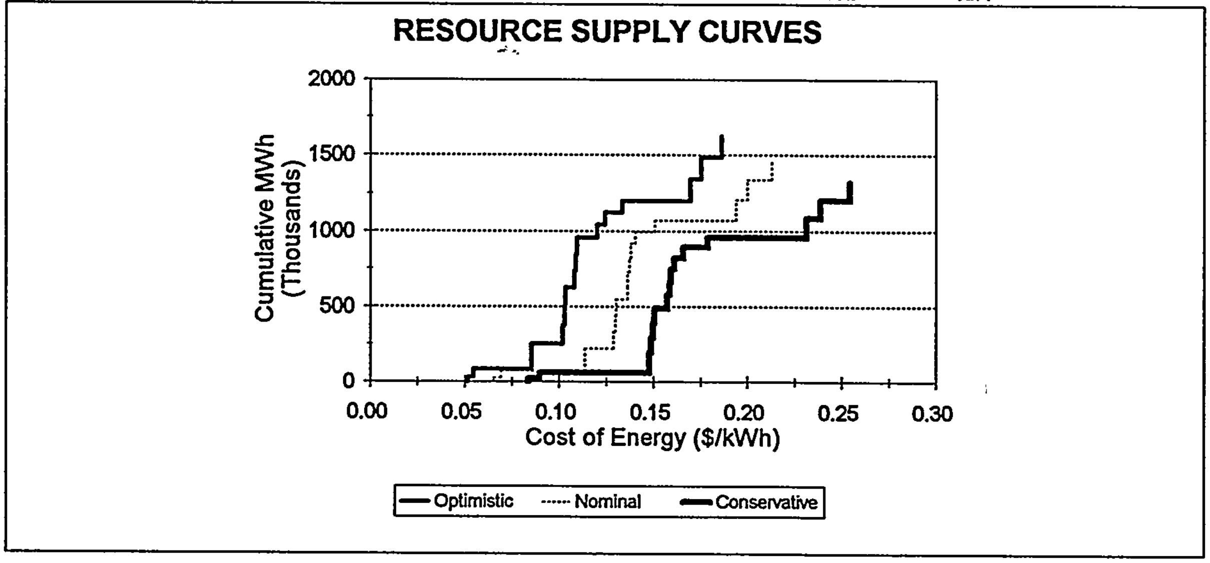


Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Optimistic	25	2	30	168,630	0.0299
Biomass Fuel	org waste-methanol	Maui	Puunene	Future	Incl	Optimistic	47	2	30	319,738	0.0352
Wind		Maui	McGregor Point	Future	Incl	Optimistic	10	1	30	28,715	0.0388
Biomass Fuel	tree crops-methanol	Maui	Paia-Puunene	Future	Incl	Optimistic	95	2	30	639,477	0.0424
Wind		Maui	NW Haleakala	Future	Incl	Optimistic	10	1	30	24,741	0.0452
Wave		Maui	Opana Point	Future	Incl	Optimistic	60	2	30	265,780	0.0485
Biomass Fuel	grass crops-methanol	Maui	Paia-Puunene	Future	Incl	Optimistic	95	2	30	639,477	0.0491
Wave		Maui	Lower Paia	Future	Incl	Optimistic	60	2	30	255,885	0.0504
Wave		Maui	Waiehu Point	Future	Incl	Optimistic	30	2	30	126,887	0.0542
Wind		Maui	Puunene	Future	Incl	Optimistic	10	1	30	18,501	0.0555
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Optimistic	50	2	30	337,260	0.0578
Wind		Maui	West Maui	Future	Incl	Optimistic	50	1	30	90,891	0.0581
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Optimistic	30	2	30	95,327	0.0647
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Optimistic	30	2	30	89,461	0.0682
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Optimistic	30	2	30	89,883	0.0687
Solar Thermal	dish	Maui	Puunene	Future	Incl	Optimistic	10	1.5	30	17,252	0.0781
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Optimistic	30	2	30	73,329	0.0784
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Optimistic	30	2	30	73,329	0.0795
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Optimistic	30	2	30	73,076	0.0798
Solar Thermal	dish	Maui	Kihei	Future	Incl	Optimistic	10	1.5	30	17,768	0.0805
Solar Thermal	dish	Maui	Kahului	Future	Incl	Optimistic	10	1.5	30	16,735	0.0853
Biomass Elec	grass crops	Maui	Paia-Puunene	Future	Incl	Optimistic	50	2	30	337,260	0.1049
Solar Thermal	trough	Maui	Puunene	Future	Incl	Optimistic	30	1.5	30	59,946	0.1562
Solar Thermal	trough	Maui	Kihei	Future	Incl	Optimistic	30	1.5	30	61,741	0.1564
Solar Thermal	trough	Maui	Kahului	Future	Incl	Optimistic	30	1.5	30	58,152	0.1656
Wind		Maui	McGregor Point	Future	Incl	Nominal	10	1	30	24,611	0.0465
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Nominal	25	2	30	153,300	0.0515
Wind		Maui	NW Haleakala	Future	Incl	Nominal	10	1	30	21,205	0.0545
Biomass Fuel	org waste-methanol	Maui	Puunene	Future	Incl	Nominal	47	2	30	290,671	0.0561
Biomass Fuel	tree crops-methanol	Maui	Paia-Puunene	Future	Incl	Nominal	95	2	30	581,342	0.0583
Biomass Fuel	grass crops-methanol	Maui	Paia-Puunene	Future	Incl	Nominal	95	2	30	581,342	0.0675
Wind		Maui	Puunene	Future	Incl	Nominal	10	1	30	15,784	0.0677
Wind		Maui	West Maui	Future	Incl	Nominal	50	1	30	77,546	0.0707
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	2	30	306,600	0.0795
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Nominal	30	2	30	82,893	0.0807
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Nominal	30	2	30	77,792	0.0850
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Nominal	30	2	30	78,159	0.0857
Solar Thermal	dish	Maui	Puunene	Future	Incl	Nominal	10	1.5	30	16,430	0.0901
Wave		Maui	Opana Point	Future	Incl	Nominal	60	2	30	211,984	0.0920

Solar Thermal	dish	Maui	Kihei	Future	Incl	Nominal	10	1.5	30	16,922	0.0929
Wave		Maui	Lower Paia	Future	Incl	Nominal	60	2	30	203,974	0.0956
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Nominal	30	2	30	63,764	0.0980
Solar Thermal	dish	Maui	Kahului	Future	Incl	Nominal	10	1.5	30	15,938	0.0984
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Nominal	30	2	30	63,764	0.0992
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Nominal	30	2	30	63,544	0.0997
Wave		Maui	Waiehu Point	Future	Incl	Nominal	30	2	30	101,256	0.1023
Biomass Elec	grass crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	2	30	306,600	0.1442
Solar Thermal	trough	Maui	Puunene	Future	Incl	Nominal	30	1.5	30	57,092	0.1778
Solar Thermal	trough	Maui	Kihei	Future	Incl	Nominal	30	1.5	30	58,801	0.1781
Solar Thermal	trough	Maui	Kahului	Future	Incl	Nominal	30	1.5	30	55,382	0.1886
Wind		Maui	McGregor Point	Future	Incl	Conservative	10	1	30	20,805	0.0592
Wind		Maui	NW Haleakala	Future	Incl	Conservative	10	1	30	17,926	0.0695
Biomass Fuel	tree crops-methanol	Maui	Paia-Puunene	Future	Incl	Conservative	95	2	30	523,208	0.0777
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Conservative	25	2	30	137,970	0.0779
Biomass Fuel	org waste-methanol	Maui	Puunene	Future	Incl	Conservative	47	2	30	261,604	0.0815
Wind		Maui	Puunene	Future	Incl	Conservative	10	1	30	13,275	0.0872
Biomass Fuel	grass crops-methanol	Maui	Paia-Puunene	Future	Incl	Conservative	95	2	30	523,208	0.0900
Wind		Maui	West Maui	Future	Incl	Conservative	50	1	30	65,218	0.0905
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Conservative	30	2	30	70,459	0.0990
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Conservative	30	2	30	66,123	0.1042
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Conservative	30	2	30	66,435	0.1051
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Conservative	50	2	30	275,940	0.1060
Solar Thermal	dish	Maui	Puunene	Future	Incl	Conservative	10	1.5	30	14,787	0.1085
Solar Thermal	dish	Maui	Kihei	Future	Incl	Conservative	10	1.5	30	15,230	0.1119
Solar Thermal	dish	Maui	Kahului	Future	Incl	Conservative	10	1.5	30	14,344	0.1187
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Conservative	30	2	30	54,199	0.1200
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Conservative	30	2	30	54,199	0.1216
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Conservative	30	2	30	54,012	0.1221
Biomass Elec	grass crops	Maui	Paia-Puunene	Future	Incl	Conservative	50	2	30	275,940	0.1922
Solar Thermal	trough	Maui	Puunene	Future	Incl	Conservative	30	1.5	30	51,383	0.2122
Solar Thermal	trough	Maui	Kihei	Future	Incl	Conservative	30	1.5	30	52,921	0.2127
Solar Thermal	trough	Maui	Kahului	Future	Incl	Conservative	30	1.5	30	49,844	0.2254
Wave		Maui	Opana Point	Future	Incl	Conservative	60	2	30	98,882	0.2913
Wave		Maui	Lower Paia	Future	Incl	Conservative	60	2	30	94,151	0.3060
Wave		Maui	Waiehu Point	Future	Incl	Conservative	30	2	30	46,754	0.3260

Island(s): Oahu
Technology: All Technologies
Stage: Current Technology
Certainty: Optimistic, Nominal, and Conservative
Trans. Cost: Cost Included

Valuation: Constant Dollars
Financing: Utility
Tax Credits: Included
Data: Unique Location Lowest COE
Avoided Cost: N/A

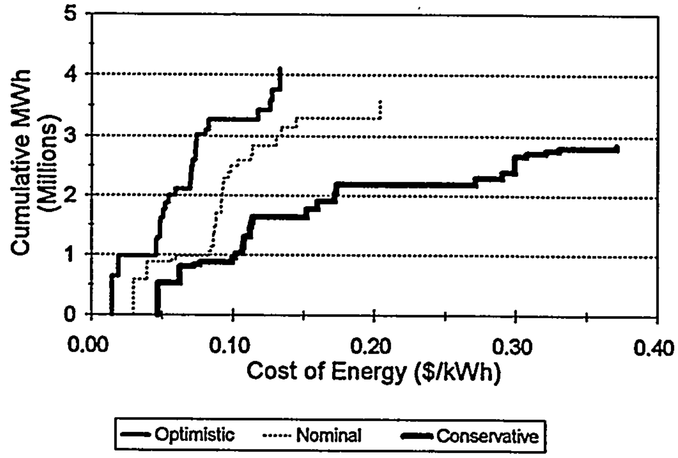


Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Oahu	Kaena Point	Current	Incl	Optimistic	15	1	30	29,553	0.0518
Wind		Oahu	Kahuku	Current	Incl	Optimistic	30	1	30	53,588	0.0548
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Optimistic	25	2	30	168,630	0.0857
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Optimistic	50	4	30	123,931	0.1026
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Optimistic	50	4	30	123,931	0.1032
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Optimistic	50	4	30	123,931	0.1038
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Optimistic	50	4	30	110,654	0.1084
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Optimistic	50	4	30	110,654	0.1091
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Optimistic	50	4	30	110,654	0.1097
Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Optimistic	50	1.5	30	84,949	0.1205
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Optimistic	50	1.5	30	80,912	0.1243
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Optimistic	50	1.5	30	78,489	0.1335
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Optimistic	80	1.5	30	146,581	0.1700
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Optimistic	80	1.5	30	139,614	0.1755
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Optimistic	80	1.5	30	135,434	0.1866
Wind		Oahu	Kaena Point	Current	Incl	Nominal	15	1	30	25,230	0.0652
Wind		Oahu	Kahuku	Current	Incl	Nominal	30	1	30	45,551	0.0694
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Nominal	25	2	30	153,300	0.1139
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Nominal	50	4	30	107,766	0.1288
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Nominal	50	4	30	107,766	0.1297
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	4	30	107,766	0.1303
Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Nominal	50	1.5	30	80,904	0.1360
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Nominal	50	4	30	96,220	0.1364
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Nominal	50	4	30	96,220	0.1373
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	4	30	96,220	0.1381
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Nominal	50	1.5	30	77,059	0.1403
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	1.5	30	74,752	0.1509
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Nominal	80	1.5	30	139,601	0.1939
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Nominal	80	1.5	30	132,966	0.2001
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Nominal	80	1.5	30	128,985	0.2130
Wind		Oahu	Kaena Point	Current	Incl	Conservative	15	1	30	21,234	0.0841
Wind		Oahu	Kahuku	Current	Incl	Conservative	30	1	30	38,147	0.0901
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Conservative	25	2	30	137,970	0.1483
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Conservative	50	4	30	96,990	0.1491
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Conservative	50	4	30	96,990	0.1501
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Conservative	50	4	30	96,990	0.1509
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Conservative	50	4	30	86,598	0.1577
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Conservative	50	4	30	86,598	0.1588
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Conservative	50	4	30	86,598	0.1597

Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Conservative	50	1.5	30	72,814	0.1612
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Conservative	50	1.5	30	69,353	0.1661
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Conservative	50	1.5	30	67,276	0.1791
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Conservative	80	1.5	30	125,641	0.2317
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Conservative	80	1.5	30	119,669	0.2391
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Conservative	80	1.5	30	116,086	0.2548

Island(s):	**Oahu**	**Valuation:**	Constant Dollars
Technology:	**All Technologies**	**Financing:**	Utility
Stage:	**Future Technology**	**Tax Credits:**	Included
Certainty:	**Optimistic, Nominal, and Conservative**	**Data:**	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	**Avoided Cost:**	N/A

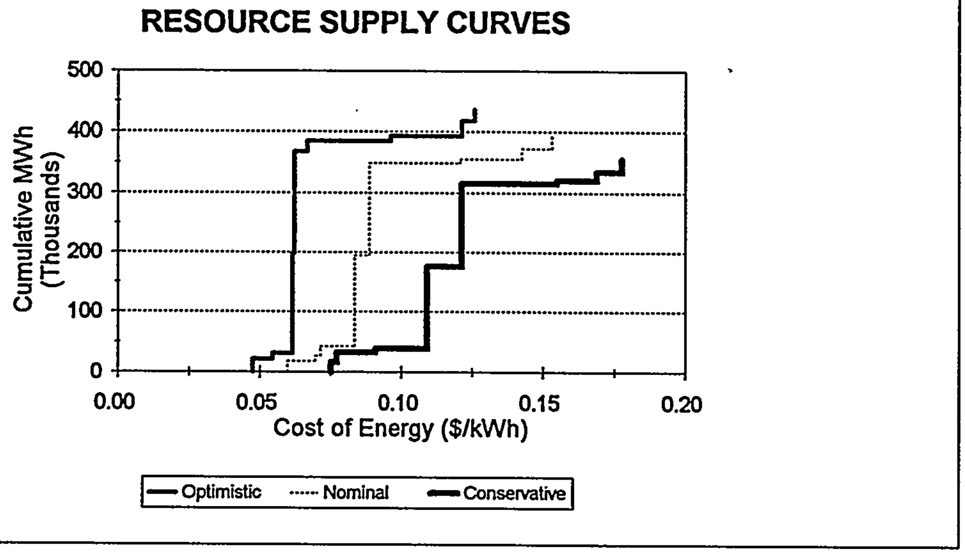
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Fuel	org waste-methanol	Oahu	Barber's Point	Future	Incl	Optimistic	95	2	30	639,477	0.0149
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Optimistic	50	2	30	337,260	0.0194
Wave		Oahu	Makapuu	Future	Incl	Optimistic	60	2	30	279,377	0.0461
Wind		Oahu	Kaena Point	Future	Incl	Optimistic	15	1	30	36,966	0.0470
Wave		Oahu	Kahuku Point	Future	Incl	Optimistic	60	2	30	265,253	0.0486
Wind		Oahu	Kahuku	Future	Incl	Optimistic	30	1	30	67,029	0.0491
Wave		Oahu	NE Coast 2A	Future	Incl	Optimistic	30	2	30	129,936	0.0511
Wave		Oahu	NE Coast 2C	Future	Incl	Optimistic	30	2	30	126,276	0.0525
Wave		Oahu	Mokapu Point	Future	Incl	Optimistic	30	2	30	122,913	0.0547
Wave		Oahu	Waimanalo Bay	Future	Incl	Optimistic	30	2	30	111,677	0.0595
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Optimistic	50	3	30	128,426	0.0700
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Optimistic	50	3	30	128,426	0.0704
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Optimistic	50	3	30	128,426	0.0708
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Optimistic	50	1.5	30	89,197	0.0719
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Optimistic	50	1.5	30	84,957	0.0735
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Optimistic	50	3	30	114,667	0.0737
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Optimistic	50	3	30	114,667	0.0741
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Optimistic	50	3	30	114,667	0.0746
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Optimistic	50	1.5	30	82,414	0.0808
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Optimistic	25	2	30	168,630	0.0830
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Optimistic	80	1.5	30	160,556	0.1180
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Optimistic	80	1.5	30	155,749	0.1267
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Optimistic	80	1.5	30	168,568	0.1278
OTEC		Oahu	Kahe Point	Future	Incl	Optimistic	60	2	30	335,543	0.1334
Biomass Fuel	org waste-methanol	Oahu	Barber's Point	Future	Incl	Nominal	95	2	30	581,342	0.0295
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Nominal	50	2	30	306,600	0.0389
Wind		Oahu	Kaena Point	Future	Incl	Nominal	15	1	30	31,558	0.0567
Wind		Oahu	Kahuku	Future	Incl	Nominal	30	1	30	56,977	0.0597
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Nominal	50	1.5	30	84,949	0.0829
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Nominal	50	1.5	30	80,912	0.0846
Wave		Oahu	Makapuu	Future	Incl	Nominal	60	2	30	224,378	0.0863
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Nominal	50	3	30	111,675	0.0873
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Nominal	50	3	30	111,675	0.0878
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	3	30	111,675	0.0883
Wave		Oahu	Kahuku Point	Future	Incl	Nominal	60	2	30	211,197	0.0918
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Nominal	50	3	30	99,710	0.0921
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Nominal	50	3	30	99,710	0.0926
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	3	30	99,710	0.0932
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	1.5	30	78,489	0.0933

Wave		Oahu	NE Coast 2A	Future	Incl	Nominal	30	2	30	103,704	0.0966
Wave		Oahu	NE Coast 2C	Future	Incl	Nominal	30	2	30	101,831	0.0982
Wave		Oahu	Mokapu Point	Future	Incl	Nominal	30	2	30	97,966	0.1034
Wave		Oahu	Waimanalo Bay	Future	Incl	Nominal	30	2	30	88,957	0.1128
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Nominal	25	2	30	153,300	0.1141
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Nominal	80	1.5	30	160,541	0.1307
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Nominal	80	1.5	30	152,911	0.1343
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Nominal	80	1.5	30	148,333	0.1443
OTEC		Oahu	Kahe Point	Future	Incl	Nominal	60	2	30	311,260	0.2041
Biomass Fuel	org waste-methanol	Oahu	Barber's Point	Future	Incl	Conservative	95	2	30	523,208	0.0473
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Conservative	50	2	30	275,940	0.0627
Wind		Oahu	Kaena Point	Future	Incl	Conservative	15	1	30	26,560	0.0721
Wind		Oahu	Kahuku	Future	Incl	Conservative	30	1	30	47,716	0.0766
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Conservative	50	1.5	30	76,454	0.0999
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Conservative	50	1.5	30	72,820	0.1019
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Conservative	50	3	30	94,924	0.1070
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Conservative	50	3	30	94,924	0.1077
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Conservative	50	3	30	94,924	0.1083
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Conservative	50	1.5	30	70,640	0.1126
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Conservative	50	3	30	84,754	0.1128
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Conservative	50	3	30	84,754	0.1135
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Conservative	50	3	30	84,754	0.1142
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Conservative	25	2	30	137,970	0.1521
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Conservative	80	1.5	30	137,620	0.1599
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Conservative	80	1.5	30	133,499	0.1721
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Conservative	80	1.5	30	144,487	0.1734
Wave		Oahu	Makapuu	Future	Incl	Conservative	60	2	30	105,316	0.2716
Wave		Oahu	Kahuku Point	Future	Incl	Conservative	60	2	30	98,372	0.2907
OTEC		Oahu	Kahe Point	Future	Incl	Conservative	60	2	30	270,789	0.2997
Wave		Oahu	NE Coast 2A	Future	Incl	Conservative	30	2	30	48,075	0.3078
Wave		Oahu	NE Coast 2C	Future	Incl	Conservative	30	2	30	45,998	0.3214
Wave		Oahu	Mokapu Point	Future	Incl	Conservative	30	2	30	45,087	0.3311
Wave		Oahu	Waimanalo Bay	Future	Incl	Conservative	30	2	30	39,939	0.3710

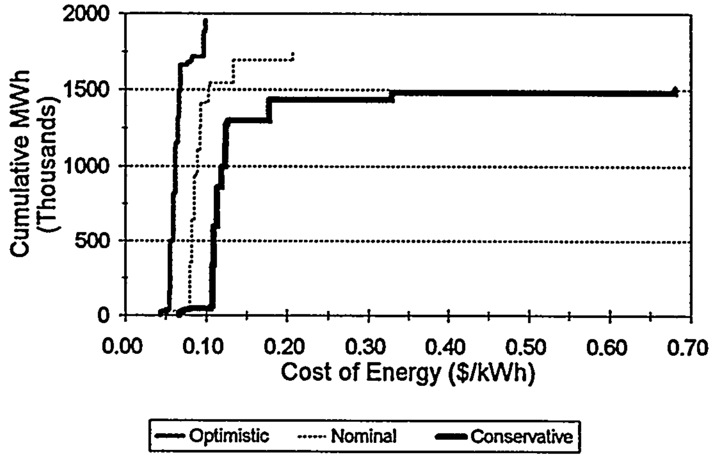
Island(s):	Kauai	Valuation:	Constant Dollars
Technology:	All Technologies	Financing:	Utility
Stage:	Current Technology	Tax Credits:	Included
Certainty:	Optimistic, Nominal, and Conservative	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	N/A



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Current	Incl	Optimistic	10	1	30	21,296	0.0475
Wind		Kauai	Port Allen	Current	Incl	Optimistic	5	1	30	9,111	0.0546
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Optimistic	25	2	30	168,630	0.0617
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Optimistic	25	2	30	168,630	0.0622
Hydro		Kauai	Wailua River	Current	Incl	Optimistic	6.6	2	50	16,770	0.0667
Wind		Kauai	Anahola	Current	Incl	Optimistic	7	1	30	7,800	0.0963
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Optimistic	10	2	30	25,483	0.1215
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Optimistic	10	1.5	30	17,250	0.1262
Wind		Kauai	N. Hanapepe	Current	Incl	Nominal	10	1	30	18,252	0.0598
Wind		Kauai	Port Allen	Current	Incl	Nominal	5	1	30	7,763	0.0696
Hydro		Kauai	Wailua River	Current	Incl	Nominal	6.6	2	50	16,435	0.0712
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Nominal	25	2	30	153,300	0.0834
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Nominal	25	2	30	153,300	0.0886
Wind		Kauai	Anahola	Current	Incl	Nominal	7	1	30	6,651	0.1210
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Nominal	10	1.5	30	16,428	0.1427
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Nominal	10	2	30	22,159	0.1533
Hydro		Kauai	Wailua River	Current	Incl	Conservative	6.6	2	50	16,267	0.0753
Wind		Kauai	N. Hanapepe	Current	Incl	Conservative	10	1	30	15,430	0.0774
Wind		Kauai	Port Allen	Current	Incl	Conservative	5	1	30	6,519	0.0909
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Conservative	25	2	30	137,970	0.1094
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Conservative	25	2	30	137,970	0.1215
Wind		Kauai	Anahola	Current	Incl	Conservative	7	1	30	5,589	0.1552
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Conservative	10	1.5	30	14,786	0.1691
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Conservative	10	2	30	19,943	0.1777

Island(s):	**Kauai**	Valuation:	Constant Dollars
Technology:	**All Technologies**	Financing:	Utility
Stage:	**Future Technology**	Tax Credits:	Included
Certainty:	**Optimistic, Nominal, and Conservative**	Data:	Unique Location Lowest COE
Trans. Cost:	**Cost Included**	Avoided Cost:	N/A

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Future	Incl	Optimistic	10	1	30	26,372	0.0440
Wind		Kauai	Port Allen	Future	Incl	Optimistic	5	1	30	10,940	0.0494
Wave		Kauai	Anahola	Future	Incl	Optimistic	30	2	30	124,296	0.0548
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Optimistic	50	2	30	337,260	0.0561
Biomass Fuel	tree crops-methanol	Kauai	Lihue	Future	Incl	Optimistic	47	2	30	319,738	0.0598
Biomass Fuel	tree crops-methanol	Kauai	Kaumakani	Future	Incl	Optimistic	47	2	30	319,738	0.0619
Hydro		Kauai	Wailua River	Future	Incl	Optimistic	6.6	2	50	16,770	0.0635
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Optimistic	25	2	30	168,630	0.0650
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Optimistic	25	2	30	168,630	0.0675
Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Optimistic	25	2	30	168,630	0.0681
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Optimistic	10	1.5	30	18,112	0.0762
Wind		Kauai	Anahola	Future	Incl	Optimistic	7	1	30	9,618	0.0803
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Optimistic	10	1	30	26,407	0.0828
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Optimistic	25	2	30	168,630	0.0972
Wave		Kauai	Barking Sands	Future	Incl	Optimistic	30	2	30	71,415	0.0996
Wind		Kauai	N. Hanapepe	Future	Incl	Nominal	10	1	30	22,602	0.0529
Wind		Kauai	Port Allen	Future	Incl	Nominal	5	1	30	9,321	0.0603
Hydro		Kauai	Wailua River	Future	Incl	Nominal	6.6	2	50	16,435	0.0678
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Nominal	50	2	30	306,600	0.0794
Biomass Fuel	tree crops-methanol	Kauai	Lihue	Future	Incl	Nominal	47	2	30	290,671	0.0822
Biomass Fuel	tree crops-methanol	Kauai	Kaumakani	Future	Incl	Nominal	47	2	30	290,671	0.0852
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Nominal	10	1.5	30	17,250	0.0878
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Nominal	25	2	30	153,300	0.0894
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Nominal	25	2	30	153,300	0.0929
Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Nominal	25	2	30	153,300	0.0937
Wind		Kauai	Anahola	Future	Incl	Nominal	7	1	30	8,200	0.0984
Wave		Kauai	Anahola	Future	Incl	Nominal	30	2	30	98,947	0.1030
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Nominal	10	1	30	22,962	0.1037
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Nominal	25	2	30	153,300	0.1336
Wave		Kauai	Barking Sands	Future	Incl	Nominal	30	2	30	51,793	0.2072
Wind		Kauai	N. Hanapepe	Future	Incl	Conservative	10	1	30	19,107	0.0673
Hydro		Kauai	Wailua River	Future	Incl	Conservative	6.6	2	50	16,267	0.0717
Wind		Kauai	Port Allen	Future	Incl	Conservative	5	1	30	7,828	0.0780
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Conservative	10	1.5	30	15,525	0.1058
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Conservative	50	2	30	275,940	0.1078
Biomass Fuel	tree crops-methanol	Kauai	Lihue	Future	Incl	Conservative	47	2	30	261,604	0.1096
Biomass Fuel	tree crops-methanol	Kauai	Kaumakani	Future	Incl	Conservative	47	2	30	261,604	0.1137
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Conservative	25	2	30	137,970	0.1191
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Conservative	25	2	30	137,970	0.1238

Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Conservative	25	2	30	137,970	0.1249
Wind		Kauai	Anahola	Future	Incl	Conservative	7	1	30	6,891	0.1264
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Conservative	10	1	30	19,518	0.1275
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Conservative	25	2	30	137,970	0.1781
Wave		Kauai	Anahola	Future	Incl	Conservative	30	2	30	45,353	0.3301
Wave		Kauai	Barking Sands	Future	Incl	Conservative	30	2	30	23,201	0.6812

APPENDIX C

TECHNOLOGY DATA SHEETS

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Methanol

Island: Hawaii   Location: Hamakua Coast   Project Code: 177,178,179

Capacity (MW):	47	Stage (current/future):	future
Resource (dry tons/year):	134,509	Extent (harvested acres/year):	1,928
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	319,738	290,671	261,604
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	319,738	290,671	261,604
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	7,229,993	9,037,491	10,844,989
Gasification	2,822,740	3,528,425	4,234,110
Gas conditioning	4,554,161	5,692,701	6,831,241
Compression	9,097,828	11,372,285	13,646,742
Acid gas removal/cooling	4,134,422	5,168,028	6,201,634
MeOH syn/purification	11,469,350	14,336,687	17,204,024
Utilities/auxiliary	9,832,370	12,290,463	14,748,555
Legal fees & permitting	594,852	743,565	892,278
General Facilities			
Road construction	1,255,528	1,569,410	1,883,292
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	4,973,572	6,216,964	7,460,357
Project contingency	5,752,874	7,191,093	8,629,311
Initial cost	2,361,846	2,952,307	3,542,768
SUB-TOTAL	65,643,461	82,054,327	98,465,192

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	6,563,948	8,204,935	9,845,922
Fixed O&M ($)	5,413,676	6,767,095	8,120,514
Land Lease	555,700	694,625	833,550
FIRST YEAR O&M	12,533,324	15,666,655	18,799,986

Note: 1 MW = 0.5274 MGPY MeOH
47 MW = 25 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: **Grass Crops - Electricity**

Island: Hawaii | Location: Hamakua Coast | Project Code: 147, 148, 149

Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons/year):	127,750	Extent (harvested acres/year):	5,079
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	6,142,154	7,226,064	8,309,973
Gasification & compressor/precooler	843,041	991,813	1,140,585
Physical cleanup	17,235,500	20,277,059	23,318,618
Ash handling	321,158	377,833	434,508
Gas turbine	334,540	393,576	452,613
Balance of plant	6,490,076	7,635,383	8,780,691
Legal fee & permitting	579,916	682,254	784,592
General Facilities			
Engineering & overhead	3,194,639	3,758,398	4,322,158
Project contingency	3,514,102	4,134,238	4,754,374
Initial cost	1,869,387	2,199,279	2,529,171
SUB-TOTAL	40,524,513	47,675,898	54,827,283

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	7,995,515	9,406,488	10,817,461
Fixed O&M ($)	2,984,000	3,510,588	4,037,176
Land Lease	226,058	265,950	305,843
FIRST YEAR O&M	11,205,573	13,183,026	15,160,480

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Hawaii	Location: Hamakua Coast	Project Code: 153,154,155	
Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons-year):	125,003	Extent (harvested acres/year):	1,771
Project Life (years):	30	Construction Time (years):	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	5,780,851	7,226,064	8,671,276
Gasification & compressor/precooler	793,450	991,813	1,190,175
Physical cleanup	16,221,647	20,277,059	24,332,471
Ash handling	302,267	377,833	453,400
Gas turbine	314,861	393,576	472,292
Balance of plant	6,108,307	7,635,383	9,162,460
Legal fee & permitting	545,803	682,254	818,705
General Facilities			
Road construction	1,153,679	1,442,098	1,730,518
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	3,006,719	3,758,398	4,510,078
Project contingency	3,579,151	4,473,939	5,368,726
Initial cost	1,440,561	1,800,701	2,160,841
SUB-TOTAL	40,811,223	51,014,026	61,216,832

TRANSMISSION			
Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ANNUAL EXPENSES			
Variable O&M ($)	4,382,632	5,478,290	6,573,948
Fixed O&M ($)	2,361,376	2,951,720	3,542,064
Land Lease	511,400	639,250	767,100
FIRST YEAR O&M	7,255,408	9,069,260	10,883,112

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Hawaii   Location: Hamakua Coast   Project Code: 150, 151, 152

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	106,500	Extent (harvested acres/year):	4,233
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,360,521	4,200,651	5,040,781
Initial cost	1,650,863	2,063,578	2,476,294
SUB-TOTAL	38,616,589	48,270,736	57,924,884

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	6,581,425	8,226,782	9,872,138
Fixed O&M ($)	2,650,361	3,312,951	3,975,541
Land Lease	178,920	223,650	268,380
FIRST YEAR O&M	9,410,706	11,763,383	14,116,059

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Hawaii   Location: Hamakua Coast   Project Code: 156, 157, 158

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	104,011	Extent (harvested acres/year):	1,447
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)		0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Road construction	942,163	1,177,704	1,413,245
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,611,130	4,513,912	5,416,694
Initial cost	1,399,778	1,749,722	2,099,667
SUB-TOTAL	41,122,203	51,402,753	61,683,304

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	3,925,696	4,907,120	5,888,544
Fixed O&M ($)	2,450,369	3,062,961	3,675,553
Land Lease	419,400	524,250	629,100
FIRST YEAR O&M	6,795,465	8,494,331	10,193,197

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops & Organic Wastes - Electricity

Island: Hawaii — Location: Hilo Coast — Project Code: 180, 181, 182

Capacity (MW electricity):	50	Stage (current/future):	future
Resource (tree crops)(dry tons/year):	170,228	Extent (harvested acres/year):	3,007
organic wastes (wet tons/yr):	67,732		
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	6,747,266	8,434,082	10,120,898
Feed handling and prep.	8,370,725	10,463,407	12,556,088
Gasification & compressor/precooler	14,769,967	18,462,459	22,154,951
Physical cleanup	904,943	1,131,179	1,357,415
Ash handling	872,624	1,090,780	1,308,936
Gas turbine	19,617,878	24,522,347	29,426,816
Balance of plant	11,139,421	13,924,276	16,709,131
Legal fees & permitting	611,189	763,986	916,783
General Facilities			
Road construction	1,958,357	2,447,946	2,937,535
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	6,303,401	7,879,252	9,455,102
Project contingency	7,218,497	9,023,121	10,827,746
Initial cost	2,635,698	3,294,622	3,953,546
SUB-TOTAL	82,713,893	103,392,365	124,070,837

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	5,821,404	7,937,811	10,052,880
Fixed O&M ($)	3,929,130	4,911,412	5,893,695
Land Lease	861,400	1,076,750	1,292,100
FIRST YEAR O&M	10,611,934	13,925,973	17,238,675

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Methanol

Island: Hawaii | Location: Hilo Coast | Project Code: 174,175,176

Capacity (MW):	47	Stage (current/future):	future
Resource (dry tons/year):	134,509	Extent (harvested acres/year)	2,335
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	319,738	290,671	261,604
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	319,738	290,671	261,604
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	7,229,993	9,037,491	10,844,989
Gasification	2,822,740	3,528,425	4,234,110
Gas conditioning	4,554,161	5,692,701	6,831,241
Compression	9,097,828	11,372,285	13,646,742
Acid gas removal/cooling	4,134,422	5,168,028	6,201,634
MeOH syn/purification	11,469,350	14,336,687	17,204,024
Utilities/auxiliary	9,832,370	12,290,463	14,748,555
Legal fees & permitting	594,852	743,565	892,278
General Facilities			
Road construction	1,521,072	1,901,340	2,281,608
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	4,973,572	6,216,964	7,460,357
Project contingency	5,779,429	7,224,286	8,669,143
Initial cost	2,417,880	3,022,350	3,626,820
SUB-TOTAL	65,991,594	82,489,492	98,987,391

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	6,969,620	8,712,025	10,454,430
Fixed O&M ($)	5,466,785	6,833,481	8,200,178
Land Lease	671,200	839,000	1,006,800
FIRST YEAR O&M	13,107,605	16,384,506	19,661,408

Note: 1 MW = 0.5274 MGPY MeOH
47 MW = 25 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Hawaii | Location: Hilo Coast | Project Code: 159, 160, 161

Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons/year):	125,003	Extent (harvested acres/year):	2,161
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	6,142,154	7,226,064	8,309,973
Gasification & compressor/precooler	843,041	991,813	1,140,585
Physical cleanup	17,235,500	20,277,059	23,318,618
Ash handling	321,158	377,833	434,508
Gas turbine	334,540	393,576	452,613
Balance of plant	6,490,076	7,635,383	8,780,691
General Facilities			
Road construction	1,495,466	1,759,371	2,023,277
Plantation lab	119,517	140,608	161,699
Equip. repair shop	1,542,155	1,814,300	2,086,445
Engineering & overhead	3,136,647	3,690,173	4,243,699
Project contingency	3,766,025	4,430,618	5,095,211
Initial cost	1,573,111	1,850,718	2,128,326
SUB-TOTAL	42,999,390	50,587,516	58,175,645

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	5,068,277	5,962,678	6,857,080
Fixed O&M ($)	2,562,898	3,015,175	3,467,451
Land Lease	660,663	777,250	893,838
FIRST YEAR O&M	8,291,838	9,755,103	11,218,369

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Hawaii   Location: Hilo Coast   Project Code: 162,163,164

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	104,011	Extent (harvested acres/year):	1,779
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)		0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Road construction	1,158,737	1,448,421	1,738,105
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,632,787	4,540,984	5,449,180
Initial cost	1,445,459	1,806,824	2,168,188
SUB-TOTAL	41,406,114	51,757,643	62,109,172

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	4,262,393	5,327,992	6,393,590
Fixed O&M ($)	2,493,684	3,117,104	3,740,525
Land Lease	513,600	642,000	770,400
FIRST YEAR O&M	7,269,677	9,087,096	10,904,515

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: **Grass Crops - Electricity**

Island: Hawaii   Location: Hilo Coast   Project Code: 171, 172, 173

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	106,500	Extent (harvested acres/year):	5,108
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,360,521	4,200,651	5,040,781
Initial cost	1,797,867	2,247,334	2,696,800
SUB-TOTAL	38,763,593	48,454,491	58,145,390

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	7,693,338	9,616,673	11,540,007
Fixed O&M ($)	2,949,687	3,687,108	4,424,530
Land Lease	213,920	267,400	320,880
FIRST YEAR O&M	10,856,945	13,571,181	16,285,417

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Hawaii   Location: Ka'u   Project Code: 168,169,170

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	106,500	Extent (harvested acres/year):	3,780
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,360,521	4,200,651	5,040,781
Initial cost	1,574,757	1,968,446	2,362,135
SUB-TOTAL	38,540,483	48,175,604	57,810,724

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	6,005,772	7,507,215	9,008,658
Fixed O&M ($)	2,495,395	3,119,244	3,743,093
Land Lease	160,800	201,000	241,200
FIRST YEAR O&M	8,661,967	10,827,459	12,992,951

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Methanol

Island: Hawaii   Location: Kaumakai   Project Code: 165, 166, 167

Capacity (MW):	47	Stage (current/future):	future
Resource (dry tons/year):	138,122	Extent (harvested acres/year):	5,492
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	319,738	290,671	261,604
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	319,738	290,671	261,604
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	7,229,993	9,037,491	10,844,989
Gasification	2,822,740	3,528,425	4,234,110
Gas conditioning	4,554,161	5,692,701	6,831,241
Compression	9,097,828	11,372,285	13,646,742
Acid gas removal/cooling	4,134,422	5,168,028	6,201,634
MeOH syn/purification	11,469,350	14,336,687	17,204,024
Utilities/auxiliary	9,832,370	12,290,463	14,748,555
Legal fees & permitting	594,852	743,565	892,278
General Facilities			
Engineering & overhead	4,973,572	6,216,964	7,460,357
Project contingency	5,470,929	6,838,661	8,206,393
Initial cost	2,716,543	3,395,678	4,074,814
SUB-TOTAL	62,896,759	78,620,948	94,345,138

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	9,959,144	12,448,930	14,938,715
Fixed O&M ($)	5,981,682	7,477,103	8,972,524
Land Lease	229,280	286,600	343,920
FIRST YEAR O&M	16,170,106	20,212,633	24,255,159

Note: 1 MW = 0.5274 MGPY MeOH
47 MW = 25 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT #3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Geothermal

Island: Hawaii Location: Kilauea Project Code: 733, 734, 735

Capacity (MW)	50	Stage (current/future)	Future
Resource	High-Temperature	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	5

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	402,960	385,440	350,400
Expected Losses (%)	3%	6%	12%
Net Energy (MWh/yr)	390,871	362,314	308,352
CAPITAL COSTS			
Process Capital			
Exploration & Assessment	175,000	1,750,000	3,500,000
Production & Injection Wells	19,600,000	30,000,000	54,400,000
Gathering/Injection System	3,850,000	4,550,000	5,250,000
Power Plant	49,500,000	56,100,000	62,700,000
Substation Tie-In	312,500	375,000	500,000
Water Supply	750,000	1,500,000	1,875,000
Permitting, Legal, Environmental	625,000	750,000	675,000
General Facilities			
Roads & Site Work	800,000	1,200,000	1,800,000
Control and Office Buildings	437,500	562,500	687,500
Land Acquisition	218,750	306,250	437,500
Engineering & Overhead	7,595,625	9,671,875	13,132,500
Project Contingency	8,355,188	10,639,063	14,445,750
Initial Costs	2,839,712	3,610,578	4,883,973
SUB-TOTAL	95,059,274	121,015,266	164,287,223
Capital Cost per kW (excl. trans)	*$1,895*	*$2,413*	*$3,276*
TRANSMISSION	0	0	0
Capital Cost per kW (incl. trans.)	*$1,901*	*$2,420*	*$3,285*
ANNUAL EXPENSES			
Variable O&M	280,000	428,571	1,066,667
Fixed O&M	990,000	1,196,250	1,402,500
Land Lease	2,286,597	1,978,232	1,282,744
FIRST YEAR O&M	3,556,597	3,603,054	3,751,911
O&M per kWh (mills)	*9.1*	*9.9*	*12.2*

HAWAII ENERGY STRATEGY
PROJECT #3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Geothermal

Island: Hawaii Location: Kilauea Project Code: 730, 731, 732

Capacity (MW)	25	Stage (current/future)	Future
Resource	High-Temperature	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	5

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	201,480	192,720	175,200
Expected Losses (%)	4%	8%	14%
Net Energy (MWh/yr)	193,421	177,302	150,672
CAPITAL COSTS			
Process Capital			
Exploration & Assessment	100,000	1,000,000	2,000,000
Production & Injection Wells	11,200,000	18,000,000	32,000,000
Gathering/Injection System	2,200,000	2,600,000	3,000,000
Power Plant	30,000,000	34,000,000	38,000,000
Substation Tie-In	250,000	300,000	400,000
Water Supply	500,000	1,000,000	1,250,000
Permitting, Legal, Environmental	500,000	600,000	700,000
General Facilities			
Roads & Site Work	500,000	750,000	1,000,000
Control and Office Buildings	350,000	450,000	550,000
Land Acquisition	125,000	175,000	250,000
Engineering & Overhead	4,547,500	5,857,500	7,875,000
Project Contingency	5,002,250	6,443,250	8,662,500
Initial Costs	1,700,743	2,186,689	2,929,458
SUB-TOTAL	56,975,493	73,362,439	98,616,958
Capital Cost per kW (excl. trans)	*$2,269*	*$2,922*	*$3,945*
TRANSMISSION	0	0	0
Capital Cost per kW (incl. trans.)	*$2,279*	*$2,934*	*$3,945*
ANNUAL EXPENSES			
Variable O&M	186,667	300,000	640,000
Fixed O&M	600,000	725,000	850,000
Land Lease	1,131,512	968,071	626,796
FIRST YEAR O&M	1,918,178	1,993,071	2,116,796
O&M per kWh (mills)	*9.9*	*11.2*	*14.0*

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: HYDRO

Island: Hawaii | Location: Umauma Stream | Project Code: 240, 241, 242

Capacity (MW) 13.8
Resource(cfs, max) 260
Project Life (years) 50

Stage (current/future) current
Extent (ft of head) 835
Construction Time (years) 2.0

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	42952	42093	41663
Expected Losses (%)	4.5%	4.5%	4.5%
Net Energy (MWh/yr)	41019	40199	39788
CAPITAL COSTS			
Process Capital			
Intake Structure	$210,910	$221,456	$232,528
Penstock	$6,082,365	$6,386,483	$6,705,807
Tailrace	$287,345	$301,712	$316,798
Diversion Structure	$1,530,378	$1,606,897	$1,687,242
Powerhouse	$1,056,829	$1,109,670	$1,165,154
Turbine	$1,957,186	$2,055,045	$2,157,798
Generator	$2,624,413	$2,755,634	$2,893,415
Switchgear	$549,370	$576,839	$605,680
Equipment Installation	$180,725	$189,761	$199,249
Interconnection	$880,643	$924,675	$970,909
Legal Fees & Permitting	$550,000	$577,500	$606,375
Environmental Moinitoring	$375,620	$394,401	$414,121
General Capital Facilities			
Access Road	$542,813	$569,954	$598,451
Station Service	$180,725	$189,761	$199,249
Telecommunications	$48,000	$50,400	$52,920
Engineering Services			
Engineering	$1,364,586	$1,432,815	$1,504,456
Construction Management	$1,364,586	$1,432,815	$1,504,456
Post Construction Environmental	$85,000	$89,250	$93,713
Project Contingency	10.0%	10.0%	10.0%
SUB-TOTAL	$21,858,643	$22,951,575	$24,099,154
TRANSMISSION			
Cost of Upgrade	$1,000,000	$1,000,000	$1,000,000
ANNUAL EXPENSES			
Variable O&M	$71,500	$75,075	$78,829
Fixed O&M	$105,722	$111,008	$116,559
Rep. Spare Parts (Sinking Fund)	$21,859	$22,952	$24,100
Land Lease	$21,000	$22,050	$23,153
Federal Fees	$9,100	$9,555	$10,033
FIRST YEAR O&M	$229,181	$240,640	$252,672

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: HYDRO

Island: Hawaii | Location: Umauma Stream | Project Code: 243, 244, 245

Capacity (MW) 13.8
Resource(cfs, max) 260
Project Life (years) 50

Stage (current/future) future
Extent (ft of head) 835
Construction Time (years) 2.0

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	42952	42093	41663
Expected Losses (%)	4.5%	4.5%	4.5%
Net Energy (MWh/yr)	41019	40199	39788
CAPITAL COSTS			
Process Capital			
Intake Structure	$210,910	$221,456	$232,528
Penstock	$6,082,365	$6,386,483	$6,705,807
Tailrace	$287,345	$301,712	$316,798
Diversion Structure	$1,530,378	$1,606,897	$1,687,242
Powerhouse	$1,056,829	$1,109,670	$1,165,154
Turbine	$1,957,186	$2,055,045	$2,157,798
Generator	$2,624,413	$2,755,634	$2,893,415
Switchgear	$549,370	$576,839	$605,680
Equipment Installation	$180,725	$189,761	$199,249
Interconnection	$880,643	$924,675	$970,909
Legal Fees & Permitting	$550,000	$577,500	$606,375
Environmental Moinitoring	$375,620	$394,401	$414,121
General Capital Facilities			
Access Road	$542,813	$569,954	$598,451
Station Service	$180,725	$189,761	$199,249
Telecommunications	$48,000	$50,400	$52,920
Engineering Services			
Engineering	$1,364,586	$1,432,815	$1,504,456
Construction Management	$1,364,586	$1,432,815	$1,504,456
Post Construction Environmental	$85,000	$89,250	$93,713
Project Contingency	10.0%	10.0%	10.0%
SUB-TOTAL	$21,858,643	$22,951,575	$24,099,154
TRANSMISSION			
Cost of Upgrade	$1,000,000	$1,000,000	$1,000,000
ANNUAL EXPENSES			
Variable O&M	$71,500	$75,075	$78,829
Fixed O&M	$52,900	$55,545	$58,322
Rep. Spare Parts (Sinking Fund)	$21,859	$22,952	$24,100
Land Lease	$21,000	$22,050	$23,153
Federal Fees	$9,100	$9,555	$10,033
FIRST YEAR O&M	$176,359	$185,177	$194,436

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: OTEC (closed cycle, ammonia)

Island: Hawaii | Location: Keahole Point | Project Code: 246, 247, 248

Project size ($MWe_{gross\ summer}$)	60	Stage (current/future)	future
Resource (ΔT, summer)	23.1°C	CWP length, intake depth	3000m, 1000m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Gross energy at constant summer ΔT (MWh/yr)	525,600	525,600	525,600
Seasonal ΔT variability factor	80%	80%	80%
Annual gross energy (MWh/yr)	420,480	420,480	420,480
Parasitic power losses	12 MWe	13 MWe	14 MWe
Net energy at 100% availability (MWh/yr)	336,384	329,376	322,368
Annual average availability	95%	90%	80%
NET ENERGY (MWh/yr)	319,565	296,438	257,894
CAPITAL COSTS ($)			
Plant structure	84,600,000	82,837,000	148,097,000
Seawater systems (pipelines and SW pumps)	57,528,000	92,778,000	186,797,000
Heat exchangers	67,680,000	138,062,000	92,966,000
Turbine/generators	56,400,000	66,270,000	11,891,000
Balance of plant	33,840,000	33,135,000	59,995,000
Substation	2,538,000	2,485,000	2,432,000
Legal fees and permitting	1,347,000	1,629,000	1,846,000
Process Capital Sub-Total	303,933,000	417,198,000	504,024,000
General Facilities	15,197,000	41,720,000	75,604,000
Engineering & Overhead	30,393,000	41,720,000	50,402,000
Project Contingency	34,952,000	50,064,000	63,003,000
Initial Costs	7,917,000	11,431,000	14,491,000
TOTAL PLANT COST	392,393,000	562,132,000	707,524,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	2,000,000	2,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	2,735,000	5,006,000	7,560,000
Amortized periodic replacements	0	0	0
FIRST YEAR O&M COST	2,735,000	5,006,000	7,560,00

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii Location: Keahole Project Code: 55, 56, 57

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	2,225	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	124,400	108,196	97,406
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**123,181**	**107,114**	**96,403**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$27,979,875	$29,452,500	$30,925,125
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$816,176	$1,020,220	$1,275,275
General Facilities			
Roads and Grading	$12,259,958	$13,622,175	$14,984,393
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$15,448,655	$15,448,655	$15,448,655
Project Contingency	$18,914,020	$18,914,020	$18,914,020
Initial Costs	$3,894,839	$3,894,839	$3,894,839
SUB-TOTAL	**$224,162,872**	**$245,326,739**	**$255,854,117**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$156,458	$173,842	$191,226
Fixed O&M	$123,500	$130,000	$136,500
Land Lease	$83,842	$88,255	$92,668
FIRST YEAR O&M	**$363,800**	**$392,097**	**$420,394**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Keahole Project Code: 598, 599, 600

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	2,225	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	139,328	121,179	109,095
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**137,963**	**119,968**	**107,971**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$41,969,813	$44,178,750	$46,387,688
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$816,176	$1,020,220	$1,275,275
General Facilities			
Roads and Grading	$12,259,958	$13,622,175	$14,984,393
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$15,448,655	$15,448,655	$15,448,655
Project Contingency	$18,914,020	$18,914,020	$18,914,020
Initial Costs	$3,894,839	$3,894,839	$3,894,839
SUB-TOTAL	**$238,152,810**	**$260,052,989**	**$271,316,679**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$234,687	$260,763	$286,839
Fixed O&M	$154,375	$162,500	$170,625
Land Lease	$83,842	$88,255	$92,668
FIRST YEAR O&M	**$472,904**	**$511,518**	**$550,132**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii Location: Keahole Project Code: 58, 59, 60

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	2,225	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	128,912	112,120	95,331
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**127,649**	**110,999**	**94,349**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$20,145,510	$21,205,800	$22,266,090
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$699,978	$874,973	$1,093,716
General Facilities			
Roads and Grading	$9,807,966	$10,897,740	$11,987,514
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$10,249,675	$10,249,675	$10,249,675
Project Contingency	$13,282,948	$13,282,948	$13,282,948
Initial Costs	$2,726,940	$2,726,940	$2,726,940
SUB-TOTAL	**$158,479,588**	**$172,279,863**	**$179,739,510**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$146,528	$162,809	$179,090
Fixed O&M	$117,032	$123,191	$129,351
Land Lease	$66,391	$69,885	$73,379
FIRST YEAR O&M	**$329,951**	**$355,885**	**$381,820**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Keahole Project Code: 601, 602, 603

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m^2)	2,225	Extent (PV module area, m^2)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	144,382	125,575	106,771
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**142,967**	**124,319**	**105,671**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$30,218,265	$31,808,700	$33,399,135
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$699,978	$874,973	$1,093,716
General Facilities			
Roads and Grading	$9,807,966	$10,897,740	$11,987,514
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$10,249,675	$10,249,675	$10,249,675
Project Contingency	$13,282,948	$13,282,948	$13,282,948
Initial Costs	$2,726,940	$2,726,940	$2,726,940
SUB-TOTAL	**$168,552,343**	**$182,882,763**	**$190,872,555**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$219,792	$244,214	$268,635
Fixed O&M	$146,290	$153,989	$161,689
Land Lease	$66,391	$69,885	$73,379
FIRST YEAR O&M	**$432,473**	**$468,088**	**$503,703**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY

PROJECT 3: RENEWABLE ENERGY ASSESSMENT

TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island Hawaii Location: Keahole Project Code: 49, 50, 51

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	74,640	64,917	58,443
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**73,908**	**64,268**	**57,841**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$17,775,450	$18,711,000	$19,646,550
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$689,987	$862,484	$1,078,105
General Facilities			
Roads and Grading	$7,514,168	$8,349,075	$9,183,983
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,388,491	$10,388,491	$10,388,491
Project Contingency	$12,654,925	$12,654,925	$12,654,925
Initial Costs	$2,619,977	$2,619,977	$2,619,977
SUB-TOTAL	**$149,764,482**	**$164,156,375**	**$171,233,893**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$93,875	$104,305	$114,736
Fixed O&M	$111,150	$117,000	$122,850
Land Lease	$50,305	$52,953	$55,601
FIRST YEAR O&M	**$255,330**	**$274,258**	**$293,186**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Keahole Project Code: 592, 593, 594

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	83,596	72,707	65,456
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**82,777**	**71,980**	**64,782**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$26,663,175	$28,066,500	$29,469,825
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$689,987	$862,484	$1,078,105
General Facilities			
Roads and Grading	$7,514,168	$8,349,075	$9,183,983
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,388,491	$10,388,491	$10,388,491
Project Contingency	$12,654,925	$12,654,925	$12,654,925
Initial Costs	$2,619,977	$2,619,977	$2,619,977
SUB-TOTAL	**$158,652,207**	**$173,511,875**	**$181,057,168**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$140,812	$156,458	$172,103
Fixed O&M	$138,938	$146,250	$153,563
Land Lease	$50,305	$52,953	$55,601
FIRST YEAR O&M	**$330,055**	**$355,661**	**$381,266**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii | Location: Keahole | Project Code: 52, 53, 54

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	2,225	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	77,347	67,272	57,198
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**76,589**	**66,599**	**56,609**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$12,798,324	$13,471,920	$14,145,516
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$611,563	$764,454	$955,568
General Facilities			
Roads and Grading	$6,011,334	$6,679,260	$7,347,186
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,881,513	$6,881,513	$6,881,513
Project Contingency	$8,867,195	$8,867,195	$8,867,195
Initial Costs	$1,831,798	$1,831,798	$1,831,798
SUB-TOTAL	**$105,652,849**	**$115,018,940**	**$120,032,378**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$87,917	$97,685	$107,454
Fixed O&M	$105,329	$110,872	$116,416
Land Lease	$39,834	$41,931	$44,028
FIRST YEAR O&M	**$233,079**	**$250,488**	**$267,897**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Keahole Project Code: 595, 596, 597

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	2,225	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	86,628	75,344	64,062
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**85,780**	**74,591**	**63,402**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$19,197,486	$20,207,880	$21,218,274
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$611,563	$764,454	$955,568
General Facilities			
Roads and Grading	$6,011,334	$6,679,260	$7,347,186
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,881,513	$6,881,513	$6,881,513
Project Contingency	$8,867,195	$8,867,195	$8,867,195
Initial Costs	$1,831,798	$1,831,798	$1,831,798
SUB-TOTAL	**$112,052,011**	**$121,754,900**	**$127,105,136**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$131,875	$146,528	$161,180
Fixed O&M	$131,661	$138,590	$145,520
Land Lease	$39,834	$41,931	$44,028
FIRST YEAR O&M	**$303,370**	**$327,049**	**$350,727**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii Location: North Kohala Project Code: 67, 68, 69

Capacity (MW)	15	Stage (current/future)	current
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	58,080
Project Life (years)	30	Construction Time (years)	2.5

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	35,565	30,932	27,848
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**35,216**	**30,623**	**27,561**
CAPITAL COSTS			
Process Capital			
PV Modules	$43,740,000	$48,600,000	$51,030,000
Array Structure & Foundations	$7,648,146	$8,050,680	$8,453,214
Power Condtioning Units	$3,729,375	$5,737,500	$6,024,375
Electrical & SCADA	$5,767,179	$5,825,434	$5,883,688
Substation	$753,021	$792,653	$832,286
Overseas Shipping	$469,965	$494,700	$519,435
Legal Fees & Permitting	$571,002	$713,752	$892,190
General Facilities			
Roads and Grading	$921,233	$1,023,593	$1,125,952
Buildings and Fencing	$160,530	$178,367	$196,204
Engineering & Overhead	$5,617,178	$5,617,178	$5,617,178
Project Contingency	$6,547,878	$6,547,878	$6,547,878
Initial Costs	$1,070,274	$1,070,274	$1,070,274
SUB-TOTAL	**$76,995,781**	**$84,652,009**	**$88,192,673**
TRANSMISSION			
Cost of Upgrade	**$1,500,000**	**$1,500,000**	**$1,500,000**
ANNUAL EXPENSES			
Variable O&M	$49,731	$55,257	$60,783
Fixed O&M	$69,469	$73,125	$76,781
Land Lease	$72,439	$76,252	$80,065
FIRST YEAR O&M	**$191,639**	**$204,634**	**$217,629**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii   Location: North Kohala   Project Code: 610, 611, 612

Capacity (MW)	15	Stage (current/future)	current
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	58,080
Project Life (years)	30	Construction Time (years)	2.5

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	39,833	34,644	31,189
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**39,442**	**34,298**	**30,868**
CAPITAL COSTS			
Process Capital			
PV Modules	$43,740,000	$48,600,000	$51,030,000
Array Structure & Foundations	$11,472,219	$12,076,020	$12,679,821
Power Condtioning Units	$3,729,375	$5,737,500	$6,024,375
Electrical & SCADA	$5,767,179	$5,825,434	$5,883,688
Substation	$753,021	$792,653	$832,286
Overseas Shipping	$469,965	$494,700	$519,435
Legal Fees & Permitting	$571,002	$713,752	$892,190
General Facilities			
Roads and Grading	$921,233	$1,023,593	$1,125,952
Buildings and Fencing	$160,530	$178,367	$196,204
Engineering & Overhead	$5,617,178	$5,617,178	$5,617,178
Project Contingency	$6,547,878	$6,547,878	$6,547,878
Initial Costs	$1,070,274	$1,070,274	$1,070,274
SUB-TOTAL	**$80,819,854**	**$88,677,349**	**$92,419,280**
TRANSMISSION			
Cost of Upgrade	**$1,500,000**	**$1,500,000**	**$1,500,000**
ANNUAL EXPENSES			
Variable O&M	$74,597	$82,886	$91,174
Fixed O&M	$86,836	$91,406	$95,977
Land Lease	$72,439	$76,252	$80,065
FIRST YEAR O&M	**$233,872**	**$250,544**	**$267,215**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii   Location: North Kohala   Project Code: 70, 71, 72

Capacity (MW)	15	Stage (current/future)	future
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	45,984
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	36,855	32,055	27,255
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**36,494**	**31,734**	**26,974**
CAPITAL COSTS			
Process Capital			
PV Modules	$30,618,000	$34,020,000	$35,721,000
Array Structure & Foundations	$5,506,666	$5,796,490	$6,086,315
Power Condtioning Units	$1,678,219	$2,581,875	$2,710,969
Electrical & SCADA	$4,547,421	$4,593,354	$4,639,288
Substation	$753,021	$792,653	$832,286
Overseas Shipping	$422,969	$445,230	$467,492
Legal Fees & Permitting	$528,459	$660,574	$825,718
General Facilities			
Roads and Grading	$736,987	$818,874	$900,761
Buildings and Fencing	$148,475	$164,972	$181,469
Engineering & Overhead	$3,715,653	$3,715,653	$3,715,653
Project Contingency	$4,555,122	$4,555,122	$4,555,122
Initial Costs	$748,471	$748,471	$748,471
SUB-TOTAL	**$53,959,461**	**$58,893,269**	**$61,384,543**
TRANSMISSION			
Cost of Upgrade	**$1,500,000**	**$1,500,000**	**$1,500,000**
ANNUAL EXPENSES			
Variable O&M	$46,575	$51,750	$56,925
Fixed O&M	$65,830	$69,295	$72,760
Land Lease	$57,362	$60,381	$63,400
FIRST YEAR O&M	**$169,767**	**$181,426**	**$193,085**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: North Kohala Project Code: 613, 614, 615

Capacity (MW)	15	Stage (current/future)	future
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	45,984
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	41,278	35,901	30,525
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**40,873**	**35,542**	**30,211**
CAPITAL COSTS			
Process Capital			
PV Modules	$30,618,000	$34,020,000	$35,721,000
Array Structure & Foundations	$8,259,998	$8,694,735	$9,129,472
Power Condtioning Units	$1,678,219	$2,581,875	$2,710,969
Electrical & SCADA	$4,547,421	$4,593,354	$4,639,288
Substation	$753,021	$792,653	$832,286
Overseas Shipping	$422,969	$445,230	$467,492
Legal Fees & Permitting	$528,459	$660,574	$825,718
General Facilities			
Roads and Grading	$736,987	$818,874	$900,761
Buildings and Fencing	$148,475	$164,972	$181,469
Engineering & Overhead	$3,715,653	$3,715,653	$3,715,653
Project Contingency	$4,555,122	$4,555,122	$4,555,122
Initial Costs	$748,471	$748,471	$748,471
SUB-TOTAL	**$56,712,794**	**$61,791,514**	**$64,427,700**
TRANSMISSION			
Cost of Upgrade	**$1,500,000**	**$1,500,000**	**$1,500,000**
ANNUAL EXPENSES			
Variable O&M	$69,863	$77,625	$85,388
Fixed O&M	$82,288	$86,619	$90,950
Land Lease	$57,362	$60,381	$63,400
FIRST YEAR O&M	**$209,512**	**$224,625**	**$239,737**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii | Location: North Kohala | Project Code: 61, 62, 63

Capacity (MW)	5	Stage (current/future)	current
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	19,360
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	11,855	10,311	9,283
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**11,739**	**10,208**	**9,187**
CAPITAL COSTS			
Process Capital			
PV Modules	$16,200,000	$18,000,000	$18,900,000
Array Structure & Foundations	$2,683,560	$2,824,800	$2,966,040
Power Condtioning Units	$1,462,500	$2,250,000	$2,362,500
Electrical & SCADA	$2,002,493	$2,022,720	$2,042,947
Substation	$264,218	$278,124	$292,030
Overseas Shipping	$161,500	$170,000	$178,500
Legal Fees & Permitting	$483,091	$603,864	$754,830
General Facilities			
Roads and Grading	$316,575	$351,750	$386,925
Buildings and Fencing	$98,183	$109,092	$120,001
Engineering & Overhead	$2,091,961	$2,091,961	$2,091,961
Project Contingency	$2,439,696	$2,439,696	$2,439,696
Initial Costs	$267,768	$267,768	$267,768
SUB-TOTAL	**$28,471,545**	**$31,409,775**	**$32,803,199**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$16,577	$18,419	$20,261
Fixed O&M	$30,875	$32,500	$34,125
Land Lease	$23,140	$24,358	$25,576
FIRST YEAR O&M	**$70,592**	**$75,277**	**$79,962**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii   Location: North Kohala   Project Code: 604, 605, 606

Capacity (MW)	5	Stage (current/future)	current
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	19,360
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	13,278	11,548	10,397
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**13,148**	**11,433**	**10,290**
CAPITAL COSTS			
Process Capital			
PV Modules	$16,200,000	$18,000,000	$18,900,000
Array Structure & Foundations	$4,025,340	$4,237,200	$4,449,060
Power Condtioning Units	$1,462,500	$2,250,000	$2,362,500
Electrical & SCADA	$2,002,493	$2,022,720	$2,042,947
Substation	$264,218	$278,124	$292,030
Overseas Shipping	$161,500	$170,000	$178,500
Legal Fees & Permitting	$483,091	$603,864	$754,830
General Facilities			
Roads and Grading	$316,575	$351,750	$386,925
Buildings and Fencing	$98,183	$109,092	$120,001
Engineering & Overhead	$2,091,961	$2,091,961	$2,091,961
Project Contingency	$2,439,696	$2,439,696	$2,439,696
Initial Costs	$267,768	$267,768	$267,768
SUB-TOTAL	**$29,813,325**	**$32,822,175**	**$34,286,219**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$24,866	$27,629	$30,391
Fixed O&M	$38,594	$40,625	$42,656
Land Lease	$23,140	$24,358	$25,576
FIRST YEAR O&M	**$86,600**	**$92,612**	**$98,624**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii | Location: North Kohala | Project Code: 64, 65, 66

Capacity (MW)	5	Stage (current/future)	future
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	15,328
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	12,285	10,685	9,085
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**12,165**	**10,578**	**8,991**
CAPITAL COSTS			
Process Capital			
PV Modules	$11,340,000	$12,600,000	$13,230,000
Array Structure & Foundations	$1,932,163	$2,033,856	$2,135,549
Power Condtioning Units	$658,125	$1,012,500	$1,063,125
Electrical & SCADA	$1,578,966	$1,594,915	$1,610,864
Substation	$264,218	$278,124	$292,030
Overseas Shipping	$145,350	$153,000	$160,650
Legal Fees & Permitting	$467,345	$584,181	$730,226
General Facilities			
Roads and Grading	$253,260	$281,400	$309,540
Buildings and Fencing	$91,370	$101,522	$111,674
Engineering & Overhead	$1,387,500	$1,387,500	$1,387,500
Project Contingency	$1,702,295	$1,702,295	$1,702,295
Initial Costs	$188,177	$188,177	$188,177
SUB-TOTAL	**$20,008,768**	**$21,917,470**	**$22,921,630**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$15,525	$17,250	$18,975
Fixed O&M	$29,258	$30,798	$32,338
Land Lease	$18,324	$19,288	$20,252
FIRST YEAR O&M	**$63,107**	**$67,336**	**$71,565**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii   Location: North Kohala   Project Code: 607, 608, 609

Capacity (MW)	5	Stage (current/future)	future
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	15,328
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	13,759	11,967	10,175
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**13,624**	**11,847**	**10,070**
CAPITAL COSTS			
Process Capital			
PV Modules	$11,340,000	$12,600,000	$13,230,000
Array Structure & Foundations	$2,898,245	$3,050,784	$3,203,323
Power Condtioning Units	$658,125	$1,012,500	$1,063,125
Electrical & SCADA	$1,578,966	$1,594,915	$1,610,864
Substation	$264,218	$278,124	$292,030
Overseas Shipping	$145,350	$153,000	$160,650
Legal Fees & Permitting	$467,345	$584,181	$730,226
General Facilities			
Roads and Grading	$253,260	$281,400	$309,540
Buildings and Fencing	$91,370	$101,522	$111,674
Engineering & Overhead	$1,387,500	$1,387,500	$1,387,500
Project Contingency	$1,702,295	$1,702,295	$1,702,295
Initial Costs	$188,177	$188,177	$188,177
SUB-TOTAL	**$20,974,850**	**$22,934,398**	**$23,989,405**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$23,288	$25,875	$28,463
Fixed O&M	$36,573	$38,498	$40,422
Land Lease	$18,324	$19,288	$20,252
FIRST YEAR O&M	**$78,184**	**$83,661**	**$89,137**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii Location: Waikoloa Project Code: 43, 44, 45

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	124,400	108,196	97,406
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**123,181**	**107,114**	**96,403**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$27,979,875	$29,452,500	$30,925,125
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$816,176	$1,020,220	$1,275,275
General Facilities			
Roads and Grading	$12,259,958	$13,622,175	$14,984,393
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$15,448,655	$15,448,655	$15,448,655
Project Contingency	$18,914,020	$18,914,020	$18,914,020
Initial Costs	$3,909,145	$3,909,145	$3,909,145
SUB-TOTAL	**$224,177,178**	**$245,341,045**	**$255,868,423**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$152,112	$169,013	$185,914
Fixed O&M	$123,500	$130,000	$136,500
Land Lease	$251,526	$264,764	$278,002
FIRST YEAR O&M	**$527,138**	**$563,777**	**$600,417**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Waikoloa Project Code: 586, 587, 588

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	139,328	121,179	109,095
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**137,963**	**119,968**	**107,971**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$41,969,813	$44,178,750	$46,387,688
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$816,176	$1,020,220	$1,275,275
General Facilities			
Roads and Grading	$12,259,958	$13,622,175	$14,984,393
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$15,448,655	$15,448,655	$15,448,655
Project Contingency	$18,914,020	$18,914,020	$18,914,020
Initial Costs	$3,909,145	$3,909,145	$3,909,145
SUB-TOTAL	**$238,167,116**	**$260,067,295**	**$271,330,985**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$228,168	$253,520	$278,871
Fixed O&M	$154,375	$162,500	$170,625
Land Lease	$251,526	$264,764	$278,002
FIRST YEAR O&M	**$634,068**	**$680,784**	**$727,499**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii   Location: Waikoloa   Project Code: 46, 47, 48

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	128,912	112,120	95,331
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**127,649**	**110,999**	**94,349**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$20,145,510	$21,205,800	$22,266,090
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$699,978	$874,973	$1,093,716
General Facilities			
Roads and Grading	$9,807,966	$10,897,740	$11,987,514
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$10,249,675	$10,249,675	$10,249,675
Project Contingency	$13,282,948	$13,282,948	$13,282,948
Initial Costs	$2,738,211	$2,738,211	$2,738,211
SUB-TOTAL	**$158,490,859**	**$172,291,134**	**$179,750,781**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$142,458	$158,287	$174,116
Fixed O&M	$117,032	$123,191	$129,351
Land Lease	$199,172	$209,655	$220,138
FIRST YEAR O&M	**$458,662**	**$491,133**	**$523,604**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Waikoloa Project Code: 589, 590, 591

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	144,382	125,575	106,771
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**142,967**	**124,319**	**105,671**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$30,218,265	$31,808,700	$33,399,135
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$699,978	$874,973	$1,093,716
General Facilities			
Roads and Grading	$9,807,966	$10,897,740	$11,987,514
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$10,249,675	$10,249,675	$10,249,675
Project Contingency	$13,282,948	$13,282,948	$13,282,948
Initial Costs	$2,738,211	$2,738,211	$2,738,211
SUB-TOTAL	**$168,563,614**	**$182,894,034**	**$190,883,826**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$213,687	$237,431	$261,174
Fixed O&M	$146,290	$153,989	$161,689
Land Lease	$199,172	$209,655	$220,138
FIRST YEAR O&M	**$559,149**	**$601,075**	**$643,000**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island Hawaii Location: Waikoloa Project Code: 37, 38, 39

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	74,640	64,917	58,443
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**73,909**	**64,268**	**57,841**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$17,775,450	$18,711,000	$19,646,550
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$689,987	$862,484	$1,078,105
General Facilities			
Roads and Grading	$7,514,167	$8,349,075	$9,183,982
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,388,491	$10,388,491	$10,388,491
Project Contingency	$12,654,925	$12,654,925	$12,654,925
Initial Costs	$2,628,562	$2,628,562	$2,628,562
SUB-TOTAL	**$149,773,067**	**$164,164,960**	**$171,242,477**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$91,267	$101,408	$111,549
Fixed O&M	$111,150	$117,000	$122,850
Land Lease	$150,916	$158,859	$166,802
FIRST YEAR O&M	**$353,333**	**$377,267**	**$401,201**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii | Location: Waikoloa | Project Code: 580, 581, 582

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	83,596	72,707	65,456
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**82,777**	**71,980**	**64,782**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$26,663,175	$28,066,500	$29,469,825
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$689,987	$862,484	$1,078,105
General Facilities			
Roads and Grading	$7,514,167	$8,349,075	$9,183,982
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,388,491	$10,388,491	$10,388,491
Project Contingency	$12,654,925	$12,654,925	$12,654,925
Initial Costs	$2,628,562	$2,628,562	$2,628,562
SUB-TOTAL	**$158,660,792**	**$173,520,460**	**$181,065,752**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$136,901	$152,112	$167,323
Fixed O&M	$138,938	$146,250	$153,563
Land Lease	$150,916	$158,859	$166,802
FIRST YEAR O&M	**$426,754**	**$457,221**	**$487,688**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Hawaii Location: Waikoloa Project Code: 40, 41, 42

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	77,347	67,272	57,198
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**76,589**	**66,599**	**56,609**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$12,798,324	$13,471,920	$14,145,516
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$611,563	$764,454	$955,568
General Facilities			
Roads and Grading	$6,011,334	$6,679,260	$7,347,186
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,881,513	$6,881,513	$6,881,513
Project Contingency	$8,867,195	$8,867,195	$8,867,195
Initial Costs	$1,838,261	$1,838,261	$1,838,261
SUB-TOTAL	**$105,659,312**	**$115,025,403**	**$120,038,841**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$85,475	$94,972	$104,469
Fixed O&M	$105,329	$110,872	$116,416
Land Lease	$119,503	$125,793	$132,083
FIRST YEAR O&M	**$310,307**	**$331,637**	**$352,968**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Hawaii Location: Waikoloa Project Code: 583, 584, 585

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	2,167	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	86,628	75,344	64,062
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**85,780**	**74,591**	**63,402**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$19,197,486	$20,207,880	$21,218,274
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$611,563	$764,454	$955,568
General Facilities			
Roads and Grading	$6,011,334	$6,679,260	$7,347,186
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,881,513	$6,881,513	$6,881,513
Project Contingency	$8,867,195	$8,867,195	$8,867,195
Initial Costs	$1,838,261	$1,838,261	$1,838,261
SUB-TOTAL	**$112,058,474**	**$121,761,363**	**$127,111,599**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$128,212	$142,458	$156,704
Fixed O&M	$131,661	$138,590	$145,520
Land Lease	$119,503	$125,793	$132,083
FIRST YEAR O&M	**$379,376**	**$406,841**	**$434,306**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Hawaii — Location: Keahole — Ownrshp: State — Project Code: 270, 271, 272

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.66	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		57,101	54,382	48,944
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		21.3%	20.3%	18.3%
Net Energy (MWh/yr)		55,125	52,500	47,250
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		240	266	306
Roads, buildings, fence		34	38	42
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		14	14	15
TOTAL CAPITAL COSTS	$/kWe,net	3,138	3,368	3,611
	$K	92,645	99,429	106,606

TRANSMISSION

Size (kV) — Distance (Miles) —

		OPTIMISTIC	NOMINAL	CONSERVATIVE
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	352	391	430
FIRST YEAR O&M	$K	1,543	1,688	1,799
Total O&M, cents/kWh		2.20	2.45	2.69

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Hawaii

Location: Keahole
Ownrshp: State

Project Code: 352, 353, 354

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.66	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		64,715	61,633	55,470
Expected Losses (%)		8.6%	9.0%	9.9%
Net Energy (MWh/yr)		58,890	56,086	50,477
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		731	769	808
Solar Field		1775	1972	2169
HTF System		352	371	408
BOP		798	886	975
Interconnect		37	39	41
Overseas Shipping		432	455	478
Legal Fees & Permitting		13	15	16
General Facilities				
Roads & Grading		296	329	361
Buildings; fence		97	103	108
Water supply		52	57	63
Engineering & Overhead		312	329	345
Project Contingency		391	411	432
Initial Costs		30	32	34
TOTAL CAPITAL COSTS	$/kWe,ne	5,316	5,767	6,237
	$K	159,479	173,018	187,113

TRANSMISSION

Size (kV) -- Distance (Miles) --

Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	85.81	95.34	104.88
Variable O&M	cents/kWh	1.74	1.93	2.12
Land Lease	$K	82	92	101
FIRST YEAR O&M	$K	3,679	4,034	4,318

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Hawaii	Location:	Keahole	Project Code:	273, 274, 275
		Ownrshp:	State		

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.66	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		59,956	57,101	51,391
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		22.4%	21.3%	19.2%
Net Energy (MWh/yr)		57,882	55,125	49,613
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		279	310	341
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		216	240	276
Roads, buildings, fence		34	38	42
Engineering & Overhead		86	90	95
Project Contingency		189	199	209
Initial Costs		10	11	12
TOTAL CAPITAL COSTS	$/kWe,net	1,917	2,114	2,322
	$K	56,598	62,395	68,547

TRANSMISSION

Size (kV)	–	Distance (Miles)	–		
Cost of Upgrade, $M			0	0	0

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	352	391	430
FIRST YEAR O&M	$K	1,185	1,295	1,376
Total O&M, cents/kWh		1.46	1.63	1.79

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Hawaii | Location: Keahole | Project Code: 355, 356, 357
Ownrshp: State

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.66	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		74,422	70,878	63,790
Expected Losses (%)		7.7%	8.1%	8.9%
Net Energy (MWh/yr)		67,724	64,499	58,049
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		585	615	646
Solar Field		1242	1381	1519
HTF System		264	278	306
BOP		718	798	877
Interconnect		33	35	37
Overseas Shipping		432	455	478
Legal Fees & Permitting		11	12	13
General Facilities				
Roads & Grading		266	296	325
Buildings; fence		88	92	97
Water supply		52	57	63
Engineering & Overhead		266	280	294
Project Contingency		293	308	324
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,270	4,628	5,001
	$K	128,092	138,849	150,023

TRANSMISSION

Size (kV) --	Distance (Miles)	--		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	51.49	57.21	62.93
Variable O&M	cents/kWh	1.39	1.54	1.70
Land Lease	$K	82	92	101
FIRST YEAR O&M	$K	2,567	2,803	2,974

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Hawaii | Location: N. Kohala | Ownrshp: Private | Project Code: 282, 283, 284

Capacity (MW)	15	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	6.01	Extent (# of units)	600
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	rock		

		OPTIMISTIC		NOMINAL		CONSERVATIVE
ENERGY PRODUCTION						
Gross Energy (MWh/yr)		30,470		29,019		26,117
Expected Losses (%)		3.3%		3.5%		3.8%
Capacity Factor (net)		22.8%		21.7%		19.5%
Net Energy (MWh/yr)		29,416		28,015		25,213
CAPITAL COSTS	1995$					
Process Capital		$/kWe,net		$/kWe,net		$/kWe,net
Support Structure		910		958		1006
Aximuth/Elevation Drives		222		234		246
Facets		194		204		214
Dish Control System		8		8		8
Stirling Engine/Generator		831		924		1016
Installation		311		327		343
Overseas Shipping		39		41		44
Legal Fees & Permitting		0.4		0.5		0.5
General Facilities						
Grubbing & Grading		115		128		147
Roads, buildings, fence		42		47		51
Engineering & Overhead		107		113		118
Project Contingency		252		265		278
Initial Costs		15		15		16
TOTAL CAPITAL COSTS	$/kWe,net	3,046		3,264		3,488
	$K	44,955		48,175		51,489

TRANSMISSION

Size (kV) – Distance (Miles) –

		Optimistic	Nominal	Conservative
Cost of Upgrade, $M		1.5	1.5	1.5
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	26.66	29.63	32.59
Variable O&M	cents/kWh	1.03	1.14	1.26
Land Lease	$K	135	150	165
FIRST YEAR O&M	$K	838	915	971
Total O&M, cents/kWh		2.44	2.71	2.98

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Hawaii	Location:	N. Kohala	Project Code:	285, 286, 287
		Ownrshp:	Private		

Capacity (MW)	15	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	6.01	Extent (# of units)	600
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	rock		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		31,993	30,470	27,423
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		23.9%	22.8%	20.5%
Net Energy (MWh/yr)		30,886	29,416	26,474
CAPITAL COSTS	1995$	$/kWe,net	$/kWe,net	$/kWe,net
Process Capital				
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		294	327	360
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.4	0.4	0.5
General Facilities				
Grubbing & Grading		104	115	133
Roads, buildings, fence		42	47	51
Engineering & Overhead		91	96	100
Project Contingency		189	199	209
Initial Costs		11	12	12
TOTAL CAPITAL COSTS	$/kWe,net	1,835	2,022	2,214
	$K	27,081	29,839	32,682

TRANSMISSION				
Size (kV)	–	Distance (Miles)	–	
Cost of Upgrade, $M		1.5	1.5	1.5

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	16.00	17.78	19.55
Variable O&M	cents/kWh	0.82	0.92	1.01
Land Lease	$K	135	150	165
FIRST YEAR O&M	$K	629	686	725
Total O&M, cents/kWh		1.63	1.81	1.99

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Hawaii	Location:	N. Kohala	Project Code:	276, 277, 278
		Ownrshp:	Private		

Capacity (MW)	5	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	6.01	Extent (# of units)	200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	rock		

		OPTIMISTIC		NOMINAL		CONSERVATIVE
ENERGY PRODUCTION						
Gross Energy (MWh/yr)		10,259		9,771		8,794
Expected Losses (%)		3.3%		3.5%		3.8%
Capacity Factor (net)		23.0%		21.9%		19.7%
Net Energy (MWh/yr)		9,904		9,433		8,489
CAPITAL COSTS	1995$					
Process Capital		$/kWe,net		$/kWe,net		$/kWe,net
Support Structure		910		958		1006
Aximuth/Elevation Drives		222		234		246
Facets		194		204		214
Dish Control System		8		8		8
Stirling Engine/Generator		831		924		1016
Installation		327		344		361
Overseas Shipping		41		43		45
Legal Fees & Permitting		0.9		0.9		1.0
General Facilities						
Grubbing & Grading		136		151		174
Roads, buildings, fence		59		65		72
Engineering & Overhead		126		132		139
Project Contingency		252		265		278
Initial Costs		18		19		20
TOTAL CAPITAL COSTS	$/kWe,net	3,123		3,348		3,579
	$K	15,366		16,470		17,611

TRANSMISSION

Size (kV)	--	Distance (Miles)	--		
Cost of Upgrade, $M			0	0	0

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	33.22	36.91	40.60
Variable O&M	cents/kWh	1.28	1.43	1.57
Land Lease	$K	45	50	55
FIRST YEAR O&M	$K	338	369	391
Total O&M, cents/kWh		3.02	3.35	3.69

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Hawaii	Location:	N. Kohala	Project Code:	279, 280, 281
		Ownrshp:	Private		

Capacity (MW)	5	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	6.01	Extent (# of units)	200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	rock		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		10,772	10,259	9,233
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		24.1%	23.0%	20.7%
Net Energy (MWh/yr)		10,399	9,904	8,914
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		310	344	379
Overseas Shipping		31	35	38
Legal Fees & Permitting		0.7	0.8	0.9
General Facilities				
Grubbing & Grading		122	136	156
Roads, buildings, fence		59	65	72
Engineering & Overhead		107	113	118
Project Contingency		189	199	209
Initial Costs		13	14	15
TOTAL CAPITAL COSTS	$/kWe,net	1,905	2,099	2,299
	$K	9,373	10,326	11,312

TRANSMISSION

Size (kV)	--	Distance (Miles)	--		
Cost of Upgrade, $M			0	0	0

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	19.93	22.14	24.36
Variable O&M	cents/kWh	1.03	1.14	1.26
Land Lease	$K	45	50	55
FIRST YEAR O&M	$K	251	274	289
Total O&M, cents/kWh		2.02	2.24	2.47

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Hawaii	Location: Waikoloa	Project Code:	264, 265, 266
	Ownrshp: Private		

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.51	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		55,598	52,950	47,655
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		20.8%	19.8%	17.8%
Net Energy (MWh/yr)		53,674	51,118	46,006
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		240	266	306
Roads, buildings, fence		34	38	42
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		23	24	26
TOTAL CAPITAL COSTS	$/kWe,net	3,148	3,378	3,622
	$K	92,930	99,729	106,922

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	1,445	1,605	1,766
FIRST YEAR O&M	$K	2,622	2,888	3,121
Total O&M, cents/kWh		2.24	2.49	2.73

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Hawaii
Location: Waikoloa
Ownrshp: Private
Project Code: 346, 347, 348

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.51	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		63,011	60,011	54,009
Expected Losses (%)		8.6%	9.0%	9.9%
Net Energy (MWh/yr)		57,340	54,610	49,149
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		731	769	808
Solar Field		1775	1972	2169
HTF System		352	371	408
BOP		798	886	975
Interconnect		37	39	41
Overseas Shipping		432	455	478
Legal Fees & Permitting		13	15	16
General Facilities				
Roads & Grading		296	329	361
Buildings; fence		97	103	108
Water supply		52	57	63
Engineering & Overhead		312	329	345
Project Contingency		391	411	432
Initial Costs		30	32	34
TOTAL CAPITAL COSTS	$/kWe,ne	5,316	5,767	6,237
	$K	159,479	173,018	187,113

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	85.81	95.34	104.88
Variable O&M	cents/kWh	1.74	1.93	2.12
Land Lease	$K	338	376	414
FIRST YEAR O&M	$K	3,908	4,290	4,603

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Hawaii	Location:	Waikoloa	Project Code:	267, 268, 269
		Ownrshp:	Private		

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.51	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC		NOMINAL		CONSERVATIVE
ENERGY PRODUCTION						
Gross Energy (MWh/yr)		58,378		55,598		50,038
Expected Losses (%)		3.1%		3.3%		3.6%
Capacity Factor (net)		21.8%		20.8%		18.7%
Net Energy (MWh/yr)		56,358		53,674		48,307
CAPITAL COSTS	1995$					
Process Capital		$/kWe,net		$/kWe,Oet		$/kWe,net
Support Structure		391		435		478
Aximuth/Elevation Drives		115		128		140
Facets		151		168		184
Dish Control System		5		5		6
Stirling Engine/Generator		412		458		503
Installation		279		310		341
Overseas Shipping		30		33		36
Legal Fees & Permitting		0.3		0.3		0.3
General Facilities						
Grubbing & Grading		216		240		276
Roads, buildings, fence		34		38		42
Engineering & Overhead		86		90		95
Project Contingency		189		199		209
Initial Costs		20		21		22
TOTAL CAPITAL COSTS	$/kWe,net	1,927		2,124		2,333
	$K	56,884		62,696		68,862

TRANSMISSION				
Size (kV) --	Distance (Miles)	--		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	1,445	1,605	1,766
FIRST YEAR O&M	$K	2,267	2,497	2,700
Total O&M, cents/kWh		1.48	1.65	1.81

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Hawaii	Location: Waikoloa	Project Code:	349, 350, 351
	Ownrshp: Private		

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.51	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	lava		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		72,463	69,012	62,111
Expected Losses (%)		7.7%	8.1%	8.9%
Net Energy (MWh/yr)		65,941	62,801	56,521
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		585	615	646
Solar Field		1242	1381	1519
HTF System		264	278	306
BOP		718	798	877
Interconnect		33	35	37
Overseas Shipping		432	455	478
Legal Fees & Permitting		11	12	13
General Facilities				
Roads & Grading		266	296	325
Buildings; fence		88	92	97
Water supply		52	57	63
Engineering & Overhead		266	280	294
Project Contingency		293	308	324
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,270	4,628	5,001
	$K	128,092	138,849	150,023

TRANSMISSION				
Size (kV) --	Distance (Miles)	--		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	51.49	57.21	62.93
Variable O&M	cents/kWh	1.39	1.54	1.70
Land Lease	$K	338	376	414
FIRST YEAR O&M	$K	2,799	3,061	3,261

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Hawaii Location Honokaa 2A Project Code 697, 698, 699

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	12.9	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	108,467	108,467	108,467
Wave energy absorbtion efficiency	54%	44%	22%
Absorbed energy (MWh/yr)	58,451	47,726	23,863
Conversion & sea-to-shore transmission efficiency	76%	78%	81%
Landed energy at 100% availability (MWh/yr)	44,352	37,347	19,294
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	42,134	33,612	15,435
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,378,000	1,378,000	1,378,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	630,000	640,000	650,000
Process Capital Sub-Total	16,327,000	20,457,000	24,588,000
General Facilities	816,000	2,046,000	3,688,000
Engineering & Overhead	1,633,000	2,046,000	2,459,000
Project Contingency	1,878,000	2,455,000	3,074,000
Initial Costs	455,000	638,000	869,000
TOTAL PLANT COST	21,108,000	27,642,000	34,678,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	327,000	818,000	1,475,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	501,000	1,174,000	2,317,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Hawaii Location North Kohala Project Code 694,695,696

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	11.0	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	276,814	276,814	276,814
Wave energy absorbtion efficiency	57%	47%	24%
Absorbed energy (MWh/yr)	158,555	130,194	65,097
Conversion & sea-to-shore transmission efficiency	78%	79%	81%
Landed energy at 100% availability (MWh/yr)	124,059	103,426	52,596
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	117,856	93,084	42,077
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	2,973,000	2,973,000	2,973,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	696,000	723,000	749,000
Process Capital Sub-Total	42,984,000	53,551,000	64,117,000
General Facilities	2,149,000	5,355,000	9,618,000
Engineering & Overhead	4,298,000	5,355,000	6,412,000
Project Contingency	4,943,000	6,426,000	8,015,000
Initial Costs	1,201,000	1,677,000	2,282,000
TOTAL PLANT COST	55,576,000	72,363,000	90,443,000
ONSHORE TRANSMISSION UPGRADE	4,000,000	4,000,000	4,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	860,000	2,142,000	3,847,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,362,000	3,156,000	6,226,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Hawaii Location North Kohala Project Code 691,692,693

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	11.0	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	92,271	92,271	92,271
Wave energy absorbtion efficiency	57%	47%	24%
Absorbed energy (MWh/yr)	52,852	43,398	21,699
Conversion & sea-to-shore transmission efficiency	78%	79%	81%
Landed energy at 100% availability (MWh/yr)	41,343	34,468	17,530
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	39,276	31,021	14,024
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,513,000	1,513,000	1,513,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	630,000	640,000	651,000
Process Capital Sub-Total	16,462,000	20,593,000	24,724,000
General Facilities	823,000	2,059,000	3,709,000
Engineering & Overhead	1,646,000	2,059,000	2,472,000
Project Contingency	1,893,000	2,471,000	3,090,000
Initial Costs	458,000	642,000	874,000
TOTAL PLANT COST	21,283,000	27,824,000	34,869,000
ONSHORE TRANSMISSION UPGRADE	1,500,000	1,500,000	1,500,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	329,000	824,000	1,483,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	504,000	1,180,000	2,325,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Hawaii Location Pepeekeo 2E Project Code 700,701,702

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	11.3	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	95,445	95,445	95,445
Wave energy absorbtion efficiency	58%	48%	24%
Absorbed energy (MWh/yr)	55,279	45,441	22,720
Conversion & sea-to-shore transmission efficiency	78%	79%	81%
Landed energy at 100% availability (MWh/yr)	43,124	35,988	18,363
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	40,968	32,389	14,691
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,445,000	1,445,000	1,445,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	630,000	640,000	651,000
Process Capital Sub-Total	16,394,000	20,525,000	24,656,000
General Facilities	820,000	2,053,000	3,698,000
Engineering & Overhead	1,639,000	2,053,000	2,466,000
Project Contingency	1,885,000	2,463,000	3,082,000
Initial Costs	457,000	640,000	871,000
TOTAL PLANT COST	21,196,000	27,733,000	34,773,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	328,000	821,000	1,479,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	503,000	1,177,000	2,321,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Kahua Ranch Project Code: 406,407,408
(leave blank)

Capacity (MW)	15	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	60
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	45,988	41,807	37,626
Expected Losses (%)	22%	27%	32%
Net Energy (MWh/yr)	35,735	30,396	25,475
CAPITAL COSTS			
Process Capital			
Turbines & Towers	8,394,435	9,327,150	10,259,865
Foundations	586,278	592,200	598,122
Assembly & Checkout	387,630	391,545	395,460
Electrical Infrastructure	1,287,853	1,300,862	1,313,870
Sub-Station	826,028	834,372	842,716
Overseas Shipping	290,021	292,950	295,880
Legal Fees & Permitting	258,677	323,347	404,183
General Facilities			
Roads & Grading	114,345	115,500	116,655
Control System	132,100	133,434	134,768
Control Buildings	55,484	56,045	56,605
Central Building	85,121	94,579	118,223
Engineering & Overhead	1,241,797	1,346,198	1,453,635
Project Contingency	1,365,977	1,480,818	1,598,998
Initial Costs	674,838	699,925	734,331
SUB-TOTAL	$15,700,583	$16,988,925	$18,323,312
TRANSMISSION			
Cost of Upgrade	$1,500,000	$1,500,000	$1,500,000
ANNUAL EXPENSES			
Variable O&M	206,371	159,580	147,120
Fixed O&M	206,211	208,294	210,377
Land Lease	127,121	133,812	140,503
FIRST YEAR O&M	$539,703	$501,686	$497,999

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Kahua Ranch Project Code: 409,410,411
(leave blank)

Capacity (MW)	15	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	50
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	57,523	52,293	47,064
Expected Losses (%)	22%	27%	32%
Net Energy (MWh/yr)	44,699	38,021	31,865
CAPITAL COSTS			
Process Capital			
Turbines & Towers	7,422,080	8,246,755	9,483,768
Foundations	478,794	483,630	488,466
Assembly & Checkout	319,794	323,025	326,255
Electrical Infrastructure	1,268,405	1,281,217	1,294,030
Sub-Station	826,028	834,372	842,716
Overseas Shipping	241,684	244,125	246,566
Legal Fees & Permitting	255,921	319,902	399,877
General Facilities			
Roads & Grading	95,634	96,600	97,566
Control System	108,982	110,083	111,184
Control Buildings	45,775	46,237	46,699
Central Building	85,121	94,579	118,223
Engineering & Overhead	1,114,822	1,208,052	1,345,535
Project Contingency	1,226,304	1,328,858	1,480,089
Initial Costs	655,625	674,337	718,403
SUB-TOTAL	$14,144,969	$15,291,772	$16,999,377
TRANSMISSION			
Cost of Upgrade	$1,500,000	$1,500,000	$1,500,000
ANNUAL EXPENSES			
Variable O&M	252,973	195,616	180,342
Fixed O&M	202,087	204,128	206,169
Land Lease	131,670	138,600	145,530
FIRST YEAR O&M	$586,729	$538,344	$532,041

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island: Hawaii Location: Kahua Ranch Project Code: 400, 401, 402 (leave blank)

Capacity (MW)	5	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	15,329	13,936	12,542
Expected Losses (%)	20%	25%	30%
Net Energy (MWh/yr)	12,334	10,516	8,838
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,938,052	3,264,503	3,590,953
Foundations	195,426	197,400	199,374
Assembly & Checkout	129,210	130,515	131,820
Electrical Infrastructure	429,284	433,621	437,957
Sub-Station	275,343	278,124	280,905
Overseas Shipping	96,674	97,650	98,627
Legal Fees & Permitting	241,435	301,794	377,242
General Facilities			
Roads & Grading	39,501	39,900	40,299
Control System	44,033	44,478	44,923
Control Buildings	18,495	18,682	18,868
Central Building	11,349	12,611	15,763
Engineering & Overhead	441,880	481,928	523,673
Project Contingency	486,068	530,120	576,040
Initial Costs	337,353	347,035	360,090
SUB-TOTAL	$5,684,104	$6,178,359	$6,696,534
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	71,231	55,210	51,037
Fixed O&M	68,737	69,431	70,126
Land Lease	42,374	44,604	46,834
FIRST YEAR O&M	$182,342	$169,246	$167,997

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Kahua Ranch Project Code: 403,404,405
(leave blank)

Capacity (MW)	5	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	16
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	18,407	16,734	15,061
Expected Losses (%)	20%	25%	30%
Net Energy (MWh/yr)	14,811	12,628	10,612
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,493,819	2,770,910	3,186,546
Foundations	153,214	154,762	156,309
Assembly & Checkout	102,334	103,368	104,402
Electrical Infrastructure	405,890	409,990	414,089
Sub-Station	275,343	278,124	280,905
Overseas Shipping	77,339	78,120	78,901
Legal Fees & Permitting	240,180	300,226	375,282
General Facilities			
Roads & Grading	32,017	32,340	32,663
Control System	34,874	35,227	35,579
Control Buildings	14,648	14,796	14,944
Central Building	11,349	12,611	15,763
Engineering & Overhead	384,101	419,047	469,538
Project Contingency	422,511	460,952	516,492
Initial Costs	331,156	338,395	354,267
SUB-TOTAL	$4,978,774	$5,408,865	$6,035,682
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	83,823	64,971	60,059
Fixed O&M	67,362	68,043	68,723
Land Lease	42,134	44,352	46,570
FIRST YEAR O&M	$193,320	$177,365	$175,352

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Lalamilo Wells Project Code: 424, 425, 426 (leave blank)

Capacity (MW)	50	Stage (current/future)	Current
Resource (mph, avg.)	21.1	Extent (# of units)	200
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	235,700	214,272	192,845
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	181,386	154,183	129,123
CAPITAL COSTS			
Process Capital			
Turbines & Towers	27,421,821	30,468,690	33,515,559
Foundations	1,954,260	1,974,000	1,993,740
Assembly & Checkout	1,292,099	1,305,150	1,318,202
Electrical Infrastructure	4,292,844	4,336,206	4,379,568
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	966,735	976,500	986,265
Legal Fees & Permitting	318,296	397,870	497,338
General Facilities			
Roads & Grading	376,299	380,100	383,901
Control System	440,332	444,780	449,228
Control Buildings	184,948	186,816	188,684
Central Building	85,121	94,579	118,223
Engineering & Overhead	4,008,618	4,334,593	4,663,976
Project Contingency	4,409,480	4,768,052	5,130,374
Initial Costs	1,868,787	1,922,224	2,020,053
SUB-TOTAL	$50,373,067	$54,370,801	$58,454,163
TRANSMISSION			
Cost of Upgrade	$2,000,000	$2,000,000	$2,000,000
ANNUAL EXPENSES			
Variable O&M	1,047,507	809,462	745,683
Fixed O&M	687,369	694,313	701,256
Land Lease	141,246	148,680	156,114
FIRST YEAR O&M	$1,876,122	$1,652,454	$1,603,053

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Lalamilo Wells Project Code: 427,428,429
(leave blank)

Capacity (MW)	50	Stage (current/future)	Future
Resource (mph, avg.)	21.1	Extent (# of units)	166
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	293,642	266,947	240,252
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	225,977	192,086	160,865
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,148,478	26,831,642	30,856,389
Foundations	1,589,595	1,605,652	1,621,708
Assembly & Checkout	1,061,717	1,072,442	1,083,166
Electrical Infrastructure	4,211,105	4,253,642	4,296,178
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	802,390	810,495	818,600
Legal Fees & Permitting	308,969	386,211	482,764
General Facilities			
Roads & Grading	312,682	315,840	318,998
Control System	361,821	365,476	369,130
Control Buildings	151,972	153,507	155,042
Central Building	85,121	94,579	118,223
Engineering & Overhead	3,578,728	3,867,072	4,292,925
Project Contingency	3,936,601	4,253,780	4,722,218
Initial Costs	1,797,035	1,824,606	1,952,061
SUB-TOTAL	$45,099,641	$48,616,184	$53,896,456
TRANSMISSION			
Cost of Upgrade	$2,000,000	$2,000,000	$2,000,000
ANNUAL EXPENSES			
Variable O&M	1,278,915	988,283	910,414
Fixed O&M	673,622	680,426	687,231
Land Lease	145,715	153,384	161,053
FIRST YEAR O&M	$2,098,252	$1,822,093	$1,758,698

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Lalamilo Wells Project Code: 418,419,420
(leave blank)

Capacity (MW)	30	Stage (current/future)	Current
Resource (mph, avg.)	21.1	Extent (# of units)	120
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	141,420	128,563	115,707
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	108,832	92,510	77,474
CAPITAL COSTS			
Process Capital			
Turbines & Towers	16,788,870	18,654,300	20,519,730
Foundations	1,172,556	1,184,400	1,196,244
Assembly & Checkout	775,259	783,090	790,921
Electrical Infrastructure	2,575,706	2,601,724	2,627,741
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	580,041	585,900	591,759
Legal Fees & Permitting	284,761	355,951	444,939
General Facilities			
Roads & Grading	226,611	228,900	231,189
Control System	264,199	266,868	269,537
Control Buildings	110,969	112,090	113,210
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,451,615	2,653,655	2,858,893
Project Contingency	2,696,777	2,919,020	3,144,782
Initial Costs	1,198,050	1,232,048	1,292,960
SUB-TOTAL	$30,862,592	$33,341,268	$35,885,559
TRANSMISSION			
Cost of Upgrade	$2,000,000	$2,000,000	$2,000,000
ANNUAL EXPENSES			
Variable O&M	628,504	485,677	447,410
Fixed O&M	412,422	416,588	420,753
Land Lease	84,748	89,208	93,668
FIRST YEAR O&M	$1,125,673	$991,472	$961,832

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Lalamilo Wells Project Code: 421,422,423
(leave blank)

Capacity (MW)	30	Stage (current/future)	Future
Resource (mph, avg.)	21.1	Extent (# of units)	100
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	176,893	160,811	144,730
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	136,131	115,714	96,907
CAPITAL COSTS			
Process Capital			
Turbines & Towers	14,844,159	16,493,510	18,967,537
Foundations	957,587	967,260	976,933
Assembly & Checkout	639,589	646,049	652,510
Electrical Infrastructure	2,536,810	2,562,435	2,588,059
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	483,368	488,250	493,133
Legal Fees & Permitting	279,249	349,061	436,327
General Facilities			
Roads & Grading	189,189	191,100	193,011
Control System	217,964	220,166	222,368
Control Buildings	91,549	92,474	93,399
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,197,664	2,377,363	2,642,693
Project Contingency	2,417,431	2,615,099	2,906,962
Initial Costs	1,160,807	1,179,194	1,258,592
SUB-TOTAL	$27,752,545	$29,945,284	$33,235,177
TRANSMISSION			
Cost of Upgrade	$2,000,000	$2,000,000	$2,000,000
ANNUAL EXPENSES			
Variable O&M	770,431	595,351	548,442
Fixed O&M	404,173	408,256	412,338
Land Lease	87,780	92,400	97,020
FIRST YEAR O&M	$1,262,384	$1,096,007	$1,057,801

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Lalamilo Wells Project Code: 412, 413, 414
(leave blank)

Capacity (MW)	3	Stage (current/future)	Current
Resource (mph, avg.)	21.1	Extent (# of units)	12
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	14,142	12,856	11,571
Expected Losses (%)	14%	19%	24%
Net Energy (MWh/yr)	12,109	10,366	8,750
CAPITAL COSTS			
Process Capital			
Turbines & Towers	1,762,831	1,958,702	2,154,572
Foundations	117,256	118,440	119,624
Assembly & Checkout	77,526	78,309	79,092
Electrical Infrastructure	257,571	260,172	262,774
Sub-Station	165,206	166,874	168,543
Overseas Shipping	58,004	58,590	59,176
Legal Fees & Permitting	237,833	297,291	371,614
General Facilities			
Roads & Grading	24,532	24,780	25,028
Control System	26,420	26,687	26,954
Control Buildings	11,097	11,209	11,321
Central Building	11,349	12,611	15,763
Engineering & Overhead	274,962	301,366	329,446
Project Contingency	302,459	331,503	362,391
Initial Costs	269,534	274,220	282,218
SUB-TOTAL	$3,596,579	$3,920,754	$4,268,516
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	69,931	54,419	50,534
Fixed O&M	41,242	41,659	42,075
Land Lease	8,475	8,921	9,367
FIRST YEAR O&M	$119,648	$104,999	$101,976

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location Lalamilo Wells Project Code: 415,416,417 (leave blank)

Capacity (MW)	3	Stage (current/future)	Future
Resource (mph, avg.)	21.1	Extent (# of units)	10
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	17,689	16,081	14,473
Expected Losses (%)	14%	19%	24%
Net Energy (MWh/yr)	15,147	12,966	10,945
CAPITAL COSTS			
Process Capital			
Turbines & Towers	1,558,637	1,731,819	1,991,591
Foundations	95,759	96,726	97,693
Assembly & Checkout	63,959	64,605	65,251
Electrical Infrastructure	253,681	256,243	258,806
Sub-Station	165,206	166,874	168,543
Overseas Shipping	48,337	48,825	49,313
Legal Fees & Permitting	237,260	296,575	370,719
General Facilities			
Roads & Grading	20,790	21,000	21,210
Control System	21,796	22,017	22,237
Control Buildings	9,155	9,247	9,340
Central Building	11,349	12,611	15,763
Engineering & Overhead	248,593	272,654	307,047
Project Contingency	273,452	299,920	337,751
Initial Costs	274,410	277,429	287,377
SUB-TOTAL	$3,282,384	$3,576,545	$4,002,641
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	85,722	66,708	61,945
Fixed O&M	40,417	40,826	41,234
Land Lease	8,778	9,240	9,702
FIRST YEAR O&M	$134,918	$116,774	$112,881

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location North Kohala Project Code: 436, 437, 438
(leave blank)

Capacity (MW)	15	Stage (current/future)	Current
Resource (mph, avg.)	21.9	Extent (# of units)	60
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	76,002	69,093	62,183
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	66,395	56,905	48,105
CAPITAL COSTS			
Process Capital			
Turbines & Towers	8,394,435	9,327,150	10,259,865
Foundations	654,885	661,500	668,115
Assembly & Checkout	387,630	391,545	395,460
Electrical Infrastructure	1,287,853	1,300,862	1,313,870
Sub-Station	826,028	834,372	842,716
Overseas Shipping	290,021	292,950	295,880
Legal Fees & Permitting	258,816	323,520	404,400
General Facilities			
Roads & Grading	114,345	115,500	116,655
Control System	132,100	133,434	134,768
Control Buildings	55,484	56,045	56,605
Central Building	85,121	94,579	118,223
Engineering & Overhead	1,248,672	1,353,146	1,460,656
Project Contingency	1,373,539	1,488,460	1,606,721
Initial Costs	720,767	736,399	768,701
SUB-TOTAL	$15,829,695	$17,109,461	$18,442,636
TRANSMISSION			
Cost of Upgrade	$1,500,000	$1,500,000	$1,500,000
ANNUAL EXPENSES			
Variable O&M	383,433	298,750	277,807
Fixed O&M	206,211	208,294	210,377
Land Lease	127,121	133,812	140,503
FIRST YEAR O&M	$716,765	$640,856	$628,686

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location North Kohala Project Code: 439,440,441
(leave blank)

Capacity (MW)	15	Stage (current/future)	Future
Resource (mph, avg.)	21.9	Extent (# of units)	50
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	95,066	86,423	77,781
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	83,049	71,178	60,171
CAPITAL COSTS			
Process Capital			
Turbines & Towers	7,422,080	8,246,755	9,483,768
Foundations	534,823	540,225	545,627
Assembly & Checkout	319,794	323,025	326,255
Electrical Infrastructure	1,268,405	1,281,217	1,294,030
Sub-Station	826,028	834,372	842,716
Overseas Shipping	241,684	244,125	246,566
Legal Fees & Permitting	256,034	320,043	400,054
General Facilities			
Roads & Grading	95,634	96,600	97,566
Control System	108,982	110,083	111,184
Control Buildings	45,775	46,237	46,699
Central Building	85,121	94,579	118,223
Engineering & Overhead	1,120,436	1,213,726	1,351,269
Project Contingency	1,232,480	1,335,099	1,486,396
Initial Costs	711,245	718,359	759,840
SUB-TOTAL	$14,268,521	$15,404,445	$17,110,193
TRANSMISSION			
Cost of Upgrade	$1,500,000	$1,500,000	$1,500,000
ANNUAL EXPENSES			
Variable O&M	470,018	366,213	340,540
Fixed O&M	202,087	204,128	206,169
Land Lease	131,670	138,600	145,530
FIRST YEAR O&M	$803,775	$708,940	$692,239

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location North Kohala Project Code: 430,431,432
(leave blank)

Capacity (MW)	5	Stage (current/future)	Current
Resource (mph, avg.)	21.9	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,334	23,031	20,728
Expected Losses (%)	14%	19%	24%
Net Energy (MWh/yr)	21,693	18,569	15,676
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,938,052	3,264,503	3,590,953
Foundations	218,295	220,500	222,705
Assembly & Checkout	129,210	130,515	131,820
Electrical Infrastructure	429,284	433,621	437,957
Sub-Station	275,343	278,124	280,905
Overseas Shipping	96,674	97,650	98,627
Legal Fees & Permitting	241,544	301,930	377,413
General Facilities			
Roads & Grading	39,501	39,900	40,299
Control System	44,033	44,478	44,923
Control Buildings	18,495	18,682	18,868
Central Building	39,723	44,137	55,171
Engineering & Overhead	447,015	487,404	529,964
Project Contingency	491,717	536,144	582,960
Initial Costs	352,107	358,930	371,485
SUB-TOTAL	$5,760,993	$6,256,517	$6,784,050
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	125,274	97,487	90,527
Fixed O&M	68,737	69,431	70,126
Land Lease	42,374	44,604	46,834
FIRST YEAR O&M	$236,385	$211,522	$207,487

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Hawaii Location North Kohala Project Code: 433,434,435 (leave blank)

Capacity (MW)	5	Stage (current/future)	Future
Resource (mph, avg.)	21.9	Extent (# of units)	16
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	30,421	27,656	24,890
Expected Losses (%)	14%	19%	24%
Net Energy (MWh/yr)	26,048	22,298	18,823
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,493,819	2,770,910	3,186,546
Foundations	171,143	172,872	174,601
Assembly & Checkout	102,334	103,368	104,402
Electrical Infrastructure	405,890	409,990	414,089
Sub-Station	275,343	278,124	280,905
Overseas Shipping	77,339	78,120	78,901
Legal Fees & Permitting	240,280	300,350	375,437
General Facilities			
Roads & Grading	32,017	32,340	32,663
Control System	34,874	35,227	35,579
Control Buildings	14,648	14,796	14,944
Central Building	39,723	44,137	55,171
Engineering & Overhead	388,741	424,023	475,324
Project Contingency	427,615	466,426	522,856
Initial Costs	348,178	352,037	367,285
SUB-TOTAL	$5,051,943	$5,482,717	$6,118,703
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	147,421	114,721	106,530
Fixed O&M	67,362	68,043	68,723
Land Lease	42,134	44,352	46,570
FIRST YEAR O&M	$256,917	$227,116	$221,823

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Ethanol

Island: Maui Location: Paia-Puunene Project Code: 228, 229, 230

Capacity (MW)	141	Stage (current/future):	future
Resource (dry tons/year):	454,600	Extent (harvested acres/year):	15,186
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (eq. MWh/yr)	950,832	864,392	777,953
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	950,832	864,392	777,953
CAPITAL COSTS			
Process Capital			
Biomass preparation	5,990,731	7,488,414	8,986,097
Pretreatment	19,023,199	23,778,999	28,534,799
Hexose fermentation	18,655,347	23,319,184	27,983,021
Pentose fermentation	5,202,477	6,503,096	7,803,716
Distillation & dehydration	3,258,117	4,072,646	4,887,175
Product storage & denature	2,378,591	2,973,239	3,567,887
Boiler	16,613,262	20,766,578	24,919,893
Non-boiler utilities	27,851,645	34,814,557	41,777,468
Environmental	3,442,504	4,303,130	5,163,756
Miscellaneous & control	5,334,314	6,667,892	8,001,471
Enzyme production	2,259,662	2,824,577	3,389,493
Legal fee & permitting	747,025	933,781	1,120,537
General Facilities			
Engineering & overhead	11,075,687	13,844,609	16,613,531
Project contingency	12,183,256	15,229,070	18,274,884
Initial cost	6,880,824	8,601,030	10,321,236
SUB-TOTAL	140,896,642	176,120,803	211,344,963

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	25,684,826	32,106,032	38,527,239
Fixed O&M ($)	14,921,772	18,652,214	22,382,657
Land Lease	617,040	771,300	925,560
FIRST YEAR O&M	41,223,638	51,529,546	61,835,456

Note: 1 MW = 0.355 MGPY ethanol
141 MW = 50 MGPY ethanol

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Ethanol

Island: Maui Location: Paia-Puunene Project Code: 225, 226, 227

Capacity (MW)	70	Stage (current/future):	current
Resource (dry tons/year):	454,600	Extent (harvested acres/year):	15,186
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (eq. MWh/yr)	475,416	432,196	388,977
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	475,416	432,196	388,977
CAPITAL COSTS			
SUB-TOTAL	98,125,199	115,441,410	132,757,622

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	29,891,164	35,166,075	40,440,986
Fixed O&M ($)	13,409,110	15,775,424	18,141,738
Land Lease	720,120	847,200	974,280
FIRST YEAR O&M	44,020,394	51,788,699	59,557,004

Note: 1 MW = 0.355 MGPY ethanol
70 MW = 25 MGPY ethanol

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Ethanol

Island: Maui	Location: Paia/Puunene	Project Code:	138,139,140
Capacity (MW)	70	Stage (current/future):	future
Resource (dry tons/year):	303,036	Extent (harvested acres/year):	5,029
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (eq. MWh/yr)	475,416	432,196	388,977
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	475,416	432,196	388,977
CAPITAL COSTS			
Process Capital			
Biomass preparation	3,888,024	4,860,030	5,832,036
Pretreatment	12,347,089	15,433,862	18,520,634
Hexose fermentation	12,107,926	15,134,907	18,161,889
Pentose fermentation	3,376,300	4,220,375	5,064,450
Distillation & dehydration	2,114,766	2,643,458	3,172,149
Product storage & denature	1,705,387	2,131,734	2,558,081
Boiler	10,782,830	13,478,538	16,174,245
Non-boiler utilities	18,077,319	22,596,649	27,115,979
Environmental	2,234,348	2,792,935	3,351,522
Miscellaneous & control	3,461,408	4,326,760	5,192,112
Enzyme production	1,466,224	1,832,779	2,199,335
General Facilities			
Road construction	3,275,270	4,094,088	4,912,905
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	7,221,253	9,026,566	10,831,879
Project contingency	8,427,298	10,534,122	12,640,946
Initial cost	3,923,894	4,904,867	5,885,841
SUB-TOTAL	95,973,263	119,966,579	143,959,894

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	12,367,659	15,459,574	18,551,489
Fixed O&M ($)	9,496,118	11,870,147	14,244,176
Land Lease	1,434,200	1,792,750	2,151,300
FIRST YEAR O&M	23,297,977	29,122,471	34,946,965

Note: 1 MW = 0.355 MGPY ethanol
70 MW = 25 MGPY ethanol

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Methanol

Island: Maui	Location: Paia-Puunene	Project Code:	141,142,143
Capacity (MW):	95	Stage (current/future):	future
Resource (dry tons/year):	268,910	Extent (harvested acres/year):	4,333
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	639,477	581,342	523,208
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	639,477	581,342	523,208
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	8,971,907	11,214,883	13,457,860
Gasification	3,494,321	4,367,902	5,241,482
Gas conditioning	5,645,480	7,056,850	8,468,221
Compression	11,269,974	14,087,467	16,904,961
Acid gas removal/cooling	5,131,301	6,414,126	7,696,951
MeOH syn/purification	14,208,142	17,760,178	21,312,213
Utilities/auxiliary	12,172,411	15,215,514	18,258,617
Legal fees & permitting	624,234	780,292	936,351
General Facilities			
Road construction	2,822,351	3,527,939	4,233,527
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	6,151,777	7,689,721	9,227,666
Project contingency	7,205,583	9,006,978	10,808,374
Initial cost	3,307,609	4,134,511	4,961,413
SUB-TOTAL	82,569,016	103,211,270	123,853,524

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	11,383,149	14,228,937	17,074,724
Fixed O&M ($)	6,702,933	8,378,666	10,054,399
Land Lease	1,237,200	1,546,500	1,855,800
FIRST YEAR O&M	19,323,282	24,154,103	28,984,923

Note: 1 MW = 0.5274 MGPY MeOH
95 MW = 50 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Methanol

Island: Maui   Location: Paia-Puunene   Project Code: 394, 395, 396

Capacity (MW):	95	Stage (current/future):	future
Resource (dry tons/year):	276,300	Extent (harvested acres/year):	9,229
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	639,477	581,342	523,208
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	639,477	581,342	523,208
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	8,971,907	11,214,883	13,457,860
Gasification	3,494,321	4,367,902	5,241,482
Gas conditioning	5,645,480	7,056,850	8,468,221
Compression	11,269,974	14,087,467	16,904,961
Acid gas removal/cooling	5,131,301	6,414,126	7,696,951
MeOH syn/purification	14,208,142	17,760,178	21,312,213
Utilities/auxiliary	12,172,411	15,215,514	18,258,617
Legal fees & permitting	624,234	780,292	936,351
General Facilities			
Engineering & overhead	6,151,777	7,689,721	9,227,666
Project contingency	6,766,955	8,458,693	10,150,432
Initial cost	3,768,540	4,710,675	5,652,810
SUB-TOTAL	78,205,042	97,756,303	117,307,563

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	15,400,534	19,250,667	23,100,800
Fixed O&M ($)	8,235,952	10,294,940	12,353,928
Land Lease	378,760	473,450	568,140
FIRST YEAR O&M	24,015,246	30,019,057	36,022,868

Note: 1 MW = 0.5274 MGPY MeOH
95 MW = 50 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Maui | Location: Paia-Puunene | Project Code: 121,122,123

Capacity (MW):	50	Stage (current/future):	current
Resource (dry tons/year):	255,500	Extent (harvested acres/year):	8,536
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	10,221,685	12,025,511	13,829,338
Gasification & compressor/precooler	15,178,000	17,856,470	20,534,941
Physical cleanup	24,186,360	28,454,541	32,722,722
Ash handling	526,537	619,455	712,374
Gas turbine	503,644	592,522	681,401
Balance of plant	10,118,666	11,904,313	13,689,960
Legal fee & permitting	653,337	768,632	883,927
General Facilities			
Engineering & overhead	6,138,823	7,222,145	8,305,466
Project contingency	6,752,705	7,944,359	9,136,013
Initial cost	3,388,630	3,986,623	4,584,617
SUB-TOTAL	77,668,386	91,374,572	105,080,758

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	13,801,037	16,236,514	18,671,992
Fixed O&M ($)	5,378,455	6,327,595	7,276,734
Land Lease	372,980	438,800	504,620
FIRST YEAR O&M	19,552,472	23,002,909	26,453,346

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Maui   Location: Paia-Puunene   Project Code: 133,134,135

Capacity (MW):	50	Stage (current/future):	current
Resource (dry tons/year):	250,006	Extent (harvested acres/year):	3,982
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	9,620,409	12,025,511	14,430,613
Gasification & compressor/precooler	14,285,176	17,856,470	21,427,764
Physical cleanup	22,763,633	28,454,541	34,145,449
Ash handling	495,564	619,455	743,346
Gas turbine	474,018	592,522	711,027
Balance of plant	9,523,451	11,904,313	14,285,176
Legal fee & permitting	614,906	768,632	922,358
General Facilities			
Road construction	2,593,363	3,241,704	3,890,044
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	5,777,716	7,222,145	8,666,573
Project contingency	6,771,216	8,464,020	10,156,824
Initial cost	2,766,838	3,458,548	4,150,257
SUB-TOTAL	77,250,215	96,562,769	115,875,323

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	9,258,133	11,572,666	13,887,199
Fixed O&M ($)	3,720,325	4,650,406	5,580,487
Land Lease	1,137,600	1,422,000	1,706,400
FIRST YEAR O&M	14,116,058	17,645,072	21,174,086

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Maui | Location: Paia-Puunene | Project Code: 124,125,126

Capacity (MW electricity):	50	Stage (current/future):	future
Resource (dry tons-year):	212,917	Extent (harvested acres/year):	7,114
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	8,370,725	10,463,407	12,556,088
Gasification & compressor/precooler	14,769,967	18,462,459	22,154,951
Physical cleanup	904,943	1,131,179	1,357,415
Ash handling	872,624	1,090,780	1,308,936
Gas turbine	19,617,878	24,522,347	29,426,816
Balance of plant	11,139,421	13,924,276	16,709,131
Legal fee & permitting	611,189	763,986	916,783
General Facilities			
Engineering & overhead	5,628,675	7,035,843	8,443,012
Project contingency	6,191,542	7,739,428	9,287,313
Initial cost	4,185,526	5,231,907	6,278,289
SUB-TOTAL	72,292,490	90,365,612	108,438,734

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	20,805,077	26,006,346	31,207,615
Fixed O&M ($)	7,144,326	8,930,407	10,716,489
Land Lease	598,000	747,500	897,000
FIRST YEAR O&M	28,547,403	35,684,253	42,821,104

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree Crops - Electricity

Island: Maui | Location: Puunene | Project Code: 213,214,215

Capacity (MW electricity):	50	Stage (current/future):	future
Resource (dry tons/year):	208,008	Extent (harvested acres/year):	3,245
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	8,370,725	10,463,407	12,556,088
Gasification & compressor/precooler	14,769,967	18,462,459	22,154,951
Physical cleanup	904,943	1,131,179	1,357,415
Ash handling	872,624	1,090,780	1,308,936
Gas turbine	19,617,878	24,522,347	29,426,816
Balance of plant	11,139,421	13,924,276	16,709,131
Legal fees & permitting	611,189	763,986	916,783
General Facilities			
Road construction	2,113,775	2,642,218	3,170,662
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	5,628,675	7,035,843	8,443,012
Project contingency	6,559,312	8,199,140	9,838,968
Initial cost	2,563,155	3,203,944	3,844,733
SUB-TOTAL	74,715,591	93,394,487	112,073,385

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	7,937,833	9,922,291	11,906,750
Fixed O&M ($)	3,594,613	4,493,267	5,391,920
Land Lease	929,000	1,161,250	1,393,500
FIRST YEAR O&M	12,461,446	15,576,808	18,692,170

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Organic Wastes - Methanol

Island: Maui | Location: Puunene | Project Code: 144,145,146

Capacity (MW electricity):	47	Stage (current/future):	future
Resource (tons/year):	260,417	Extent (harvested acres/year):	N/A
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	319,738	290,671	261,604
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	319,738	290,671	261,604
CAPITAL COSTS			
Process Capital			
MSW. to RDF front-end processing	17,237,015	21,546,269	25,855,522
Feed handling, preparation	7,229,993	9,037,491	10,844,989
Gasification	2,822,740	3,528,425	4,234,110
Gas conditioning	4,554,161	5,692,701	6,831,241
Compression	9,097,828	11,372,285	13,646,742
Acid gas removal/cooling	4,134,422	5,168,028	6,201,634
MeOH syn-purification	11,469,350	14,336,687	17,204,024
Utilities/auxiliary	9,832,370	12,290,463	14,748,555
Legal fees & permitting	594,852	743,565	892,278
General Facilities			
Engineering & overhead	6,697,273	8,371,591	10,045,910
Project contingency	7,367,000	9,208,750	11,050,501
Initial cost	1,980,705	2,475,882	2,971,058
SUB-TOTAL	83,017,709	103,772,137	124,526,564

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	(1,604,364)	208,089	2,020,542
Fixed O&M ($)	5,038,530	6,298,163	7,557,795
Land Lease	9,600	12,000	14,400
FIRST YEAR O&M	3,443,766	6,518,252	9,592,737

Note: 1MW = 0.5274 MGPY MeOH
47 MW = 25 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Organic Waste - Electricity

Island: Maui | Location: Puunene | Project Code: 127,128,129

Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons/year):	224,123	Extent (harvested acres/year):	N/A
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	16,578,219	19,503,787	22,429,355
Feed handling and prep.	6,142,154	7,226,064	8,309,973
Gasification & compressor/precooler	843,041	991,813	1,140,585
Physical cleanup	17,235,500	20,277,059	23,318,618
Ash handling	321,158	377,833	434,508
Gas turbine	334,540	393,576	452,613
Balance of plant	6,490,076	7,635,383	8,780,691
Legal fees & permitting	579,916	682,254	784,592
General Facilities			
Engineering & overhead	3,194,639	3,758,398	4,322,158
Project contingency	3,514,102	4,134,238	4,754,374
Initial cost	1,430,278	1,682,680	1,935,082
SUB-TOTAL	56,663,623	66,663,085	76,662,549

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	(2,873,897)	(1,687,326)	(500,755)
Fixed O&M ($)	1,913,914	2,392,392	2,870,870
Land Lease	9,600	12,000	14,400
FIRST YEAR O&M	(950,383)	717,066	2,384,515

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Organic Wastes - Electricity

Island: Maui | Location: Puunene | Project Code: 130,131,132

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	186,951	Extent (harvested acres/year):	N/A
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	306,600	275,940
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	13,753,341	17,191,677	20,630,012
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fees & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	4,430,353	5,537,941	6,645,529
Project contingency	4,873,388	6,091,735	7,310,082
Initial cost	1,378,066	1,722,583	2,067,099
SUB-TOTAL	54,985,335	68,731,671	82,478,002

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	(2,087,892)	(1,020,782)	46,328
Fixed O&M ($)	1,945,143	2,431,429	2,917,714
Land Lease	9,600	12,000	14,400
FIRST YEAR O&M	(133,149)	1,422,647	2,978,442

HAWAII ENERGY STRATEGY

PROJECT 3: RENEWABLE ENERGY ASSESSMENT

TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui Location: Kahului Project Code: 31, 32, 33

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	71,462	62,154	55,955
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**70,762**	**61,532**	**55,379**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$14,107,500	$14,850,000	$15,592,500
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$682,265	$852,832	$1,066,040
General Facilities			
Roads and Grading	$1,804,478	$2,004,975	$2,205,473
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,078,838	$10,078,838	$10,078,838
Project Contingency	$11,760,351	$11,760,351	$11,760,351
Initial Costs	$2,550,148	$2,550,148	$2,550,148
SUB-TOTAL	**$139,105,064**	**$152,667,567**	**$158,915,211**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$80,465	$89,405	$98,346
Fixed O&M	$111,150	$117,000	$122,850
Land Lease	$150,916	$158,859	$166,802
FIRST YEAR O&M	**$342,531**	**$365,264**	**$387,997**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui   Location: Kahului   Project Code: 574, 575, 576

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m^2)	1,909	Extent (PV module area, m^2)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	92,901	80,800	72,742
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**91,990**	**79,992**	**71,992**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$21,161,250	$22,275,000	$23,388,750
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$682,265	$852,832	$1,066,040
General Facilities			
Roads and Grading	$1,804,478	$2,004,975	$2,205,473
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,078,838	$10,078,838	$10,078,838
Project Contingency	$11,760,351	$11,760,351	$11,760,351
Initial Costs	$2,550,148	$2,550,148	$2,550,148
SUB-TOTAL	**$146,158,814**	**$160,092,567**	**$166,711,461**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$120,697	$134,108	$147,518
Fixed O&M	$138,938	$146,250	$153,563
Land Lease	$150,916	$158,859	$166,802
FIRST YEAR O&M	**$410,550**	**$439,217**	**$467,883**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui Location: Kahului Project Code: 34, 35, 36

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	74,054	64,408	54,763
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**73,329**	**63,764**	**54,199**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$10,157,400	$10,692,000	$11,226,600
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$606,004	$757,505	$946,881
General Facilities			
Roads and Grading	$1,443,582	$1,603,980	$1,764,378
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,669,710	$6,669,710	$6,669,710
Project Contingency	$8,180,910	$8,180,910	$8,180,910
Initial Costs	$1,781,887	$1,781,887	$1,781,887
SUB-TOTAL	**$97,490,615**	**$106,208,792**	**$110,573,969**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$75,357	$83,730	$92,103
Fixed O&M	$105,329	$110,872	$116,416
Land Lease	$119,503	$125,793	$132,083
FIRST YEAR O&M	**$300,189**	**$320,395**	**$340,601**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui | Location: Kahului | Project Code: 577, 578, 579

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	96,271	83,731	71,193
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**95,327**	**82,893**	**70,459**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$15,236,100	$16,038,000	$16,839,900
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$606,004	$757,505	$946,881
General Facilities			
Roads and Grading	$1,443,582	$1,603,980	$1,764,378
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,669,710	$6,669,710	$6,669,710
Project Contingency	$8,180,910	$8,180,910	$8,180,910
Initial Costs	$1,781,887	$1,781,887	$1,781,887
SUB-TOTAL	**$102,569,315**	**$111,554,792**	**$116,187,269**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$113,036	$125,595	$138,155
Fixed O&M	$131,661	$138,590	$145,520
Land Lease	$119,503	$125,793	$132,083
FIRST YEAR O&M	**$364,199**	**$389,978**	**$415,757**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui   Location: Kahului   Project Code: 25, 26, 27

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,821	20,718	18,652
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**23,588**	**20,511**	**18,460**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$713,492	$713,492	$713,492
SUB-TOTAL	**$51,382,226**	**$56,518,914**	**$58,920,877**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$26,822	$29,802	$32,782
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$48,293	$50,835	$53,377
FIRST YEAR O&M	**$121,428**	**$129,387**	**$137,346**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui | Location: Kahului | Project Code: 568, 569, 570

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	30,967	26,934	24,248
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**30,664**	**26,664**	**23,998**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$7,445,625	$7,837,500	$8,229,375
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$713,492	$713,492	$713,492
SUB-TOTAL	**$53,864,101**	**$59,131,414**	**$61,664,002**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$40,233	$44,703	$49,173
Fixed O&M	$57,891	$60,938	$63,984
Land Lease	$48,293	$50,835	$53,377
FIRST YEAR O&M	**$146,417**	**$156,476**	**$166,534**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui Location: Kahului Project Code: 28, 29, 30

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	24,685	21,470	18,255
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**24,443**	**21,255**	**18,067**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,593	$499,593	$499,593
SUB-TOTAL	**$36,067,740**	**$39,391,291**	**$41,095,473**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$25,119	$27,910	$30,701
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$38,241	$40,254	$42,267
FIRST YEAR O&M	**$107,247**	**$114,361**	**$121,474**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui Location: Kahului Project Code: 571, 572, 573

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	32,091	27,911	23,731
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**31,776**	**27,632**	**23,487**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,593	$499,593	$499,593
SUB-TOTAL	**$37,854,690**	**$41,272,291**	**$43,070,523**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$37,679	$41,865	$46,052
Fixed O&M	$54,859	$57,746	$60,633
Land Lease	$38,241	$40,254	$42,267
FIRST YEAR O&M	**$130,778**	**$139,865**	**$148,951**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui Location: Kihei Project Code: 13, 14, 15

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,739	20,646	18,587
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**23,506**	**20,440**	**18,396**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$713,642	$713,642	$713,642
SUB-TOTAL	**$51,382,376**	**$56,519,064**	**$58,921,027**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$28,436	$31,595	$34,755
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$48,293	$50,835	$53,377
FIRST YEAR O&M	**$123,041**	**$131,180**	**$139,319**

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui Location: Kihei Project Code: 556, 557, 558

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	29,198	28,442	25,607
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**28,912**	**28,158**	**25,343**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$8,507,495	$8,955,258	$9,403,021
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$713,642	$713,642	$713,642
SUB-TOTAL	**$54,926,121**	**$60,249,322**	**$62,837,797**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$53,622	$59,580	$65,538
Fixed O&M	$59,606	$62,743	$65,880
Land Lease	$48,293	$50,835	$53,377
FIRST YEAR O&M	**$161,521**	**$173,158**	**$184,795**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island Maui Location: Kihei Project Code: 16, 17, 18

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	24,600	21,395	18,191
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**24,359**	**21,181**	**18,004**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,733	$499,733	$499,733
SUB-TOTAL	**$36,067,880**	**$39,391,431**	**$41,095,613**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$26,631	$29,590	$32,549
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$38,241	$40,254	$42,267
FIRST YEAR O&M	**$108,759**	**$116,041**	**$123,322**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui   Location: Kihei   Project Code: 559, 560, 561

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	30,257	26,316	22,375
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**29,961**	**26,053**	**22,145**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,733	$499,733	$499,733
SUB-TOTAL	**$37,854,830**	**$41,272,431**	**$43,070,663**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$39,947	$44,385	$48,824
Fixed O&M	$54,859	$57,746	$60,633
Land Lease	$38,241	$40,254	$42,267
FIRST YEAR O&M	**$133,046**	**$142,385**	**$151,723**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui   Location: Kihei   Project Code: 19, 20, 21

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	71,216	61,939	55,762
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**70,518**	**61,320**	**55,188**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$14,107,500	$14,850,000	$15,592,500
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$682,265	$852,832	$1,066,040
General Facilities			
Roads and Grading	$1,804,478	$2,004,975	$2,205,473
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,078,838	$10,078,838	$10,078,838
Project Contingency	$11,760,351	$11,760,351	$11,760,351
Initial Costs	$2,550,597	$2,550,597	$2,550,597
SUB-TOTAL	**$139,105,513**	**$152,668,016**	**$158,915,660**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$85,307	$94,785	$104,264
Fixed O&M	$111,150	$117,000	$122,850
Land Lease	$150,916	$158,859	$166,802
FIRST YEAR O&M	**$347,373**	**$370,644**	**$393,915**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island	Maui	Location:	Kihei	Project Code:	562, 563, 564

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	87,596	76,185	68,588
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**86,737**	**75,424**	**67,881**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$21,161,250	$22,275,000	$23,388,750
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$682,265	$852,832	$1,066,040
General Facilities			
Roads and Grading	$1,804,478	$2,004,975	$2,205,473
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,078,838	$10,078,838	$10,078,838
Project Contingency	$11,760,351	$11,760,351	$11,760,351
Initial Costs	$2,550,597	$2,550,597	$2,550,597
SUB-TOTAL	**$146,159,263**	**$160,093,016**	**$166,711,910**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$127,960	$142,178	$156,395
Fixed O&M	$138,938	$146,250	$153,563
Land Lease	$150,916	$158,859	$166,802
FIRST YEAR O&M	**$417,813**	**$447,287**	**$476,760**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui Location: Kihei Project Code: 22, 23, 24

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	73,799	64,186	54,575
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**73,076**	**63,544**	**54,012**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$10,157,400	$10,692,000	$11,226,600
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$606,004	$757,505	$946,881
General Facilities			
Roads and Grading	$1,443,582	$1,603,980	$1,764,378
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,669,710	$6,669,710	$6,669,710
Project Contingency	$8,180,910	$8,180,910	$8,180,910
Initial Costs	$1,782,307	$1,782,307	$1,782,307
SUB-TOTAL	**$97,491,035**	**$106,209,212**	**$110,574,389**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$79,893	$88,770	$97,647
Fixed O&M	$105,329	$110,872	$116,416
Land Lease	$119,503	$125,793	$132,083
FIRST YEAR O&M	**$304,725**	**$325,435**	**$346,145**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui | Location: Kihei | Project Code: 565, 566, 567

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	90,773	78,949	67,127
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	89,883	78,159	66,435
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$15,236,100	$16,038,000	$16,839,900
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$606,004	$757,505	$946,881
General Facilities			
Roads and Grading	$1,443,582	$1,603,980	$1,764,378
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,669,710	$6,669,710	$6,669,710
Project Contingency	$8,180,910	$8,180,910	$8,180,910
Initial Costs	$1,782,307	$1,782,307	$1,782,307
SUB-TOTAL	$102,569,735	$111,555,212	$116,187,689
TRANSMISSION			
Cost of Upgrade	$3,000,000	$3,000,000	$3,000,000
ANNUAL EXPENSES			
Variable O&M	$119,840	$133,155	$146,471
Fixed O&M	$131,661	$138,590	$145,520
Land Lease	$119,503	$125,793	$132,083
FIRST YEAR O&M	$371,003	$397,538	$424,073

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui — Location: Puunene — Project Code: 7, 8, 9

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	71,462	62,154	55,955
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**70,762**	**61,532**	**55,379**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$14,107,500	$14,850,000	$15,592,500
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$682,265	$852,832	$1,066,040
General Facilities			
Roads and Grading	$1,804,478	$2,004,975	$2,205,473
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,078,838	$10,078,838	$10,078,838
Project Contingency	$11,760,351	$11,760,351	$11,760,351
Initial Costs	$2,541,771	$2,541,771	$2,541,771
SUB-TOTAL	**$139,096,687**	**$152,659,190**	**$158,906,834**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$85,307	$94,785	$104,264
Fixed O&M	$111,150	$117,000	$122,850
Land Lease	$50,305	$52,953	$55,601
FIRST YEAR O&M	**$246,762**	**$264,738**	**$282,714**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui   Location: Puunene   Project Code: 550, 551, 552

Capacity (MW)	30	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	290,400
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	87,184	75,827	68,265
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**86,330**	**75,069**	**67,562**
CAPITAL COSTS			
Process Capital			
PV Modules	$77,760,000	$86,400,000	$90,720,000
Array Structure & Foundations	$23,679,232	$24,925,507	$26,171,782
Power Condtioning Units	$6,581,250	$10,125,000	$10,631,250
Electrical & SCADA	$11,173,910	$11,286,778	$11,399,645
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$920,550	$969,000	$1,017,450
Legal Fees & Permitting	$682,265	$852,832	$1,066,040
General Facilities			
Roads and Grading	$1,804,478	$2,004,975	$2,205,473
Buildings and Fencing	$258,999	$287,776	$316,554
Engineering & Overhead	$10,078,838	$10,078,838	$10,078,838
Project Contingency	$11,760,351	$11,760,351	$11,760,351
Initial Costs	$2,541,771	$2,541,771	$2,541,771
SUB-TOTAL	**$148,668,419**	**$162,734,697**	**$169,486,117**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$136,136	$151,262	$166,388
Fixed O&M	$137,977	$145,239	$152,501
Land Lease	$50,305	$52,953	$55,601
FIRST YEAR O&M	**$324,418**	**$349,454**	**$374,490**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui | Location: Puunene | Project Code: 10, 11. 12

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	74,055	64,408	54,763
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	73,329	63,764	54,199
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$10,157,400	$10,692,000	$11,226,600
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$606,004	$757,505	$946,881
General Facilities			
Roads and Grading	$1,443,582	$1,603,980	$1,764,378
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,669,710	$6,669,710	$6,669,710
Project Contingency	$8,180,910	$8,180,910	$8,180,910
Initial Costs	$1,775,318	$1,775,318	$1,775,318
SUB-TOTAL	$97,484,046	$106,202,223	$110,567,400
TRANSMISSION			
Cost of Upgrade	$3,000,000	$3,000,000	$3,000,000
ANNUAL EXPENSES			
Variable O&M	$79,893	$88,770	$97,647
Fixed O&M	$105,329	$110,872	$116,416
Land Lease	$39,834	$41,931	$44,028
FIRST YEAR O&M	$225,056	$241,573	$258,090

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui Location: Puunene Project Code: 553, 554, 555

Capacity (MW)	30	Stage (current/future)	future
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	229,920
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	90,346	78,578	66,811
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**89,461**	**77,792**	**66,123**
CAPITAL COSTS			
Process Capital			
PV Modules	$54,432,000	$60,480,000	$63,504,000
Array Structure & Foundations	$15,236,100	$16,038,000	$16,839,900
Power Condtioning Units	$2,961,563	$4,556,250	$4,784,063
Electrical & SCADA	$8,810,628	$8,899,624	$8,988,620
Substation	$1,426,776	$1,501,870	$1,576,963
Overseas Shipping	$828,495	$872,100	$915,705
Legal Fees & Permitting	$606,004	$757,505	$946,881
General Facilities			
Roads and Grading	$1,443,582	$1,603,980	$1,764,378
Buildings and Fencing	$191,661	$212,956	$234,252
Engineering & Overhead	$6,669,710	$6,669,710	$6,669,710
Project Contingency	$8,180,910	$8,180,910	$8,180,910
Initial Costs	$1,775,318	$1,775,318	$1,775,318
SUB-TOTAL	**$102,562,746**	**$111,548,223**	**$116,180,700**
TRANSMISSION			
Cost of Upgrade	**$3,000,000**	**$3,000,000**	**$3,000,000**
ANNUAL EXPENSES			
Variable O&M	$119,840	$133,155	$146,471
Fixed O&M	$131,661	$138,590	$145,520
Land Lease	$39,834	$41,931	$44,028
FIRST YEAR O&M	**$291,335**	**$313,676**	**$336,018**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui | Location: Puunene | Project Code: 1, 2, 3

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,820	20,718	18,652
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**23,587**	**20,511**	**18,460**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$710,818	$710,818	$710,818
SUB-TOTAL	**$51,379,552**	**$56,516,240**	**$58,918,203**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$28,436	$31,595	$34,755
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$16,098	$16,945	$17,792
FIRST YEAR O&M	**$90,846**	**$97,290**	**$103,734**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Maui Location: Puunene Project Code: 544, 545, 546

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	29,061	25,276	22,755
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**28,776**	**25,023**	**22,521**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$8,507,318	$8,955,072	$9,402,826
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$710,818	$710,818	$710,818
SUB-TOTAL	**$54,923,120**	**$60,246,312**	**$62,834,778**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$47,115	$52,350	$57,585
Fixed O&M	$56,172	$59,128	$62,084
Land Lease	$16,098	$16,945	$17,792
FIRST YEAR O&M	**$119,384**	**$128,423**	**$137,462**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Maui Location: Puunene Project Code: 4, 5, 6

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	24,685	21,470	18,255
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**24,443**	**21,255**	**18,067**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$497,497	$497,497	$497,497
SUB-TOTAL	**$36,065,644**	**$39,389,195**	**$41,093,377**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$26,631	$29,590	$32,549
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$12,747	$13,418	$14,089
FIRST YEAR O&M	**$83,265**	**$89,205**	**$95,144**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island Maui Location: Puunene Project Code: 547, 548, 549

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,027	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	30,116	26,193	22,271
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**29,821**	**25,931**	**22,041**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$497,497	$497,497	$497,497
SUB-TOTAL	**$37,852,594**	**$41,270,195**	**$43,068,427**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$39,947	$44,385	$48,824
Fixed O&M	$54,859	$57,746	$60,633
Land Lease	$12,747	$13,418	$14,089
FIRST YEAR O&M	**$107,552**	**$115,549**	**$123,546**

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island:	Maui	Location:	Kahului
		Ownrshp:	Private
Project Code:	370, 371, 372		

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		55,568	52,922	47,629
Expected Losses (%)		8.6%	9.0%	9.9%
Net Energy (MWh/yr)		50,567	48,159	43,343
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		731	769	808
Solar Field		1775	1972	2169
HTF System		352	371	408
BOP		798	886	975
Interconnect		37	39	41
Overseas Shipping		432	455	478
Legal Fees & Permitting		13	15	16
General Facilities				
Roads & Grading		118	131	145
Buildings; fence		97	103	108
Water supply		52	57	63
Engineering & Overhead		312	329	345
Project Contingency		391	411	432
Initial Costs		30	32	34
TOTAL CAPITAL COSTS	$/kWe,ne	5,138	5,570	6,020
	$K	154,155	167,103	180,607

TRANSMISSION				
Size (kV)	--	Distance (Miles)	--	
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	85.81	95.34	104.88
Variable O&M	cents/kWh	1.74	1.93	2.12
Land Lease	$K	384	426	469
FIRST YEAR O&M	$K	3,836	4,216	4,535

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui — Location: Kahului — Project Code: 318, 319, 320
Ownrshp: Private

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		49,030	46,695	42,026
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		18.3%	17.4%	15.7%
Net Energy (MWh/yr)		47,334	45,080	40,572
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		96	107	123
Roads, buildings, fence		34	38	42
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		24	26	27
TOTAL CAPITAL COSTS	$/kWe,net	3,005	3,220	3,440
	$K	88,720	95,049	101,536

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	1,638	1,820	2,002
FIRST YEAR O&M	$K	2,759	3,043	3,298
Total O&M, cents/kWh		2.42	2.69	2.95

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Maui	Location:	Kahului	Project Code:	321, 322, 323
		Ownrshp:	Private		

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		51,482	49,030	44,127
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		19.2%	18.3%	16.5%
Net Energy (MWh/yr)		49,700	47,334	42,600
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		279	310	341
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		86	96	110
Roads, buildings, fence		34	38	42
Engineering & Overhead		86	90	95
Project Contingency		189	199	209
Initial Costs		21	23	24
TOTAL CAPITAL COSTS	$/kWe,net	1,799	1,981	2,169
	$K	53,101	58,491	64,022

TRANSMISSION				
Size (kV)	–	Distance (Miles) –		
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	1,638	1,820	2,002
FIRST YEAR O&M	$K	2,413	2,662	2,886
Total O&M, cents/kWh		1.59	1.76	1.94

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island:	Maui	Location:	Kahului
		Ownrshp:	Private
Project Code:	373, 374, 375		

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		63,903	60,860	54,774
Expected Losses (%)		7.7%	8.1%	8.9%
Net Energy (MWh/yr)		58,152	55,382	49,844
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		585	615	646
Solar Field		1242	1381	1519
HTF System		264	278	306
BOP		718	798	877
Interconnect		33	35	37
Overseas Shipping		432	455	478
Legal Fees & Permitting		11	12	13
General Facilities				
Roads & Grading		106	118	130
Buildings; fence		88	92	97
Water supply		52	57	63
Engineering & Overhead		266	280	294
Project Contingency		293	308	324
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,110	4,451	4,806
	$K	123,301	133,525	144,167

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	51.49	57.21	62.93
Variable O&M	cents/kWh	1.39	1.54	1.70
Land Lease	$K	384	426	469
FIRST YEAR O&M	$K	2,736	2,997	3,203

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui | Location: Kahului | Project Code: 312, 313, 314
Ownrshp: Private

Capacity (MW)	10	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	400
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC		NOMINAL		CONSERVATIVE
ENERGY PRODUCTION						
Gross Energy (MWh/yr)		16,509		15,723		14,151
Expected Losses (%)		3.3%		3.5%		3.8%
Capacity Factor (net)		18.5%		17.6%		15.8%
Net Energy (MWh/yr)		15,938		15,179		13,661
CAPITAL COSTS	1995$					
Process Capital		$/kWe,net		$/kWe,net		$/kWe,net
Support Structure		910		958		1006
Aximuth/Elevation Drives		222		234		246
Facets		194		204		214
Dish Control System		8		8		8
Stirling Engine/Generator		831		924		1016
Installation		317		334		351
Overseas Shipping		40		42		44
Legal Fees & Permitting		0.6		0.6		0.6
General Facilities						
Grubbing & Grading		113		126		145
Roads, buildings, fence		48		53		58
Engineering & Overhead		113		119		125
Project Contingency		252		265		278
Initial Costs		15		16		17
TOTAL CAPITAL COSTS	$/kWe,net	3,063		3,283		3,508
	$K	30,143		32,300		34,520

TRANSMISSION

Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	28.92	32.13	35.34
Variable O&M	cents/kWh	1.12	1.24	1.37
Land Lease	$K	111	123	136
FIRST YEAR O&M	$K	578	633	676
Total O&M, cents/kWh		2.99	3.32	3.66

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui — Location: Kahului — Project Code: 315, 316, 317
Ownrshp: Private

Capacity (MW)	10	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	400
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		17,335	16,509	14,858
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		19.4%	18.5%	16.6%
Net Energy (MWh/yr)		16,735	15,938	14,344
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		301	334	367
Overseas Shipping		30	34	37
Legal Fees & Permitting		0.5	0.5	0.6
General Facilities				
Grubbing & Grading		102	113	130
Roads, buildings, fence		48	53	58
Engineering & Overhead		96	101	106
Project Contingency		189	199	209
Initial Costs		11	12	13
TOTAL CAPITAL COSTS	$/kWe,net	1,851	2,039	2,233
	$K	18,213	20,066	21,975

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	17.35	19.28	21.21
Variable O&M	cents/kWh	0.89	0.99	1.09
Land Lease	$K	111	123	136
FIRST YEAR O&M	$K	434	474	504
Total O&M, cents/kWh		1.97	2.18	2.40

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Maui   Location: Kihei   Project Code: 364, 365, 366
Ownrshp: Private

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.16	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		58,998	56,188	50,570
Expected Losses (%)		8.6%	9.0%	9.9%
Net Energy (MWh/yr)		53,688	51,131	46,018
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		731	769	808
Solar Field		1775	1972	2169
HTF System		352	371	408
BOP		798	886	975
Interconnect		37	39	41
Overseas Shipping		432	455	478
Legal Fees & Permitting		13	15	16
General Facilities				
Roads & Grading		118	131	145
Buildings; fence		97	103	108
Water supply		52	57	63
Engineering & Overhead		312	329	345
Project Contingency		391	411	432
Initial Costs		30	32	34
TOTAL CAPITAL COSTS	$/kWe,ne	5,138	5,570	6,020
	$K	154,155	167,103	180,607

TRANSMISSION
Size (kV) --   Distance (Miles) --

Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	85.81	95.34	104.88
Variable O&M	cents/kWh	1.74	1.93	2.12
Land Lease	$K	362	402	442
FIRST YEAR O&M	$K	3,868	4,248	4,565

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui
Location: Kihei
Ownrshp: Private
Project Code: 306, 307, 308

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.16	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		52,057	49,578	44,620
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		19.4%	18.5%	16.7%
Net Energy (MWh/yr)		50,256	47,862	43,076
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		96	107	123
Roads, buildings, fence		34	38	42
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		24	25	26
TOTAL CAPITAL COSTS	$/kWe,net	3,005	3,219	3,439
	$K	88,702	95,030	101,515

TRANSMISSION
Size (kV) -- Distance (Miles) --

		OPTIMISTIC	NOMINAL	CONSERVATIVE
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	1,543	1,714	1,886
FIRST YEAR O&M	$K	2,690	2,965	3,209
Total O&M, cents/kWh		2.33	2.59	2.85

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui	Location: Kihei Ownrshp: Private	Project Code:	309, 310, 311

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.16	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		54,660	52,057	46,851
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		20.4%	19.4%	17.5%
Net Energy (MWh/yr)		52,768	50,256	45,230
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		279	310	341
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		86	96	110
Roads, buildings, fence		34	38	42
Engineering & Overhead		86	90	95
Project Contingency		189	199	209
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,net	1,798	1,981	2,168
	$K	53,081	58,470	64,000

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	1,543	1,714	1,886
FIRST YEAR O&M	$K	2,339	2,579	2,793
Total O&M, cents/kWh		1.54	1.71	1.88

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Maui
Location: Kihei
Ownrshp: Private
Project Code: 367, 368, 369

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.16	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		67,847	64,617	58,155
Expected Losses (%)		7.7%	8.1%	8.9%
Net Energy (MWh/yr)		61,741	58,801	52,921
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		585	615	646
Solar Field		1242	1381	1519
HTF System		264	278	306
BOP		718	798	877
Interconnect		33	35	37
Overseas Shipping		432	455	478
Legal Fees & Permitting		11	12	13
General Facilities				
Roads & Grading		106	118	130
Buildings; fence		88	92	97
Water supply		52	57	63
Engineering & Overhead		266	280	294
Project Contingency		293	308	324
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,110	4,451	4,806
	$K	123,301	133,525	144,167

TRANSMISSION

Size (kV) -- Distance (Miles) --

Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	51.49	57.21	62.93
Variable O&M	cents/kWh	1.39	1.54	1.70
Land Lease	$K	362	402	442
FIRST YEAR O&M	$K	2,764	3,025	3,228

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Maui	Location:	Kihei	Project Code:	300, 301, 302
		Ownrshp:	Private		

Capacity (MW)	10	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.16	Extent (# of units)	400
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		17,528	16,694	15,024
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		19.6%	18.7%	16.8%
Net Energy (MWh/yr)		16,922	16,116	14,505
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		317	334	351
Overseas Shipping		40	42	44
Legal Fees & Permitting		0.6	0.6	0.6
General Facilities				
Grubbing & Grading		113	126	145
Roads, buildings, fence		48	53	58
Engineering & Overhead		113	119	125
Project Contingency		252	265	278
Initial Costs		15	16	17
TOTAL CAPITAL COSTS	$/kWe,net	3,063	3,283	3,508
	$K	30,144	32,302	34,521

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	28.92	32.13	35.34
Variable O&M	cents/kWh	1.12	1.24	1.37
Land Lease	$K	105	116	128
FIRST YEAR O&M	$K	583	638	679
Total O&M, cents/kWh		2.88	3.20	3.52

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Maui	Location:	Kihei	Project Code:	303, 304, 305
		Ownrshp:	Private		
Capacity (MW)	10		Stage (current/future)		Future
Resource (avg NIP,kWh/m2-day)	5.16		Extent (# of units)		400
Project Life (years)	30		Construction Time (years)		1.5
Geology Type	soil				

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		18,405	17,528	15,776
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		20.6%	19.6%	17.7%
Net Energy (MWh/yr)		17,768	16,922	15,230
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		301	334	367
Overseas Shipping		30	34	37
Legal Fees & Permitting		0.5	0.5	0.6
General Facilities				
Grubbing & Grading		102	113	130
Roads, buildings, fence		48	53	58
Engineering & Overhead		96	101	106
Project Contingency		189	199	209
Initial Costs		12	12	13
TOTAL CAPITAL COSTS	$/kWe,net	1,851	2,039	2,233
	$K	18,213	20,067	21,975

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	17.35	19.28	21.21
Variable O&M	cents/kWh	0.89	0.99	1.09
Land Lease	$K	105	116	128
FIRST YEAR O&M	$K	437	477	506
Total O&M, cents/kWh		1.90	2.11	2.33

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island:	Maui	Location:	Puunene	Project Code:	358, 359, 360
		Ownrshp:	State		

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		57,283	54,555	49,100
Expected Losses (%)		8.6%	9.0%	9.9%
Net Energy (MWh/yr)		52,127	49,645	44,681
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		731	769	808
Solar Field		1775	1972	2169
HTF System		352	371	408
BOP		798	886	975
Interconnect		37	39	41
Overseas Shipping		432	455	478
Legal Fees & Permitting		13	15	16
General Facilities				
Roads & Grading		118	131	145
Buildings; fence		97	103	108
Water supply		52	57	63
Engineering & Overhead		312	329	345
Project Contingency		391	411	432
Initial Costs		30	32	34
TOTAL CAPITAL COSTS	$/kWe,ne	5,138	5,570	6,020
	$K	154,155	167,103	180,607

TRANSMISSION

Size (kV)	--	Distance (Miles)	--		
Cost of Upgrade, $M			3	3	3

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	85.81	95.34	104.88
Variable O&M	cents/kWh	1.74	1.93	2.12
Land Lease	$K	93	103	114
FIRST YEAR O&M	$K	3,572	3,921	4,208

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui | Location: Puunene | Ownrshp: State | Project Code: 294, 295, 296

Capacity (MW)	30	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		50,544	48,137	43,323
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		18.9%	18.0%	16.2%
Net Energy (MWh/yr)		48,795	46,471	41,824
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		96	107	123
Roads, buildings, fence		34	38	42
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		14	14	15
TOTAL CAPITAL COSTS	$/kWe,net	2,994	3,208	3,427
	$K	88,396	94,708	101,178

TRANSMISSION

Size (kV) -- Distance (Miles) --

Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	397	441	486
FIRST YEAR O&M	$K	1,531	1,678	1,795
Total O&M, cents/kWh		2.37	2.64	2.90

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui | Location: Puunene | Project Code: 297, 298, 299
Ownrshp: State

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		53,071	50,544	45,489
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		19.8%	18.9%	17.0%
Net Energy (MWh/yr)		51,234	48,795	43,915
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		279	310	341
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.3	0.3	0.3
General Facilities				
Grubbing & Grading		86	96	110
Roads, buildings, fence		34	38	42
Engineering & Overhead		86	90	95
Project Contingency		189	199	209
Initial Costs		10	11	12
TOTAL CAPITAL COSTS	$/kWe,net	1,788	1,970	2,157
	$K	52,776	58,149	63,663

TRANSMISSION				
Size (kV)	–	Distance (Miles) –		
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	397	441	486
FIRST YEAR O&M	$K	1,183	1,295	1,381
Total O&M, cents/kWh		1.56	1.73	1.91

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Maui — Location: Puunene — Project Code: 361, 362, 363
Ownrshp: State

Capacity (MW)	30	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		65,875	62,738	56,464
Expected Losses (%)		7.7%	8.1%	8.9%
Net Energy (MWh/yr)		59,946	57,092	51,383
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		585	615	646
Solar Field		1242	1381	1519
HTF System		264	278	306
BOP		718	798	877
Interconnect		33	35	37
Overseas Shipping		432	455	478
Legal Fees & Permitting		11	12	13
General Facilities				
Roads & Grading		106	118	130
Buildings; fence		88	92	97
Water supply		52	57	63
Engineering & Overhead		266	280	294
Project Contingency		293	308	324
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,110	4,451	4,806
	$K	123,301	133,525	144,167

TRANSMISSION

Size (kV) -- Distance (Miles) --

		OPTIMISTIC	NOMINAL	CONSERVATIVE
Cost of Upgrade, $M		3	3	3
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	51.49	57.21	62.93
Variable O&M	cents/kWh	1.39	1.54	1.70
Land Lease	$K	93	103	114
FIRST YEAR O&M	$K	2,470	2,701	2,874

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Maui — Location: Puunene — Project Code: 288, 289, 290
Ownrshp: State

Capacity (MW)	10	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	400
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		17,019	16,208	14,588
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		19.1%	18.2%	16.3%
Net Energy (MWh/yr)		16,430	15,648	14,083
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		317	334	351
Overseas Shipping		40	42	44
Legal Fees & Permitting		0.6	0.6	0.6
General Facilities				
Grubbing & Grading		113	126	145
Roads, buildings, fence		48	53	58
Engineering & Overhead		113	119	125
Project Contingency		252	265	278
Initial Costs		13	14	15
TOTAL CAPITAL COSTS	$/kWe,net	3,061	3,280	3,506
	$K	30,122	32,279	34,497

TRANSMISSION
Size (kV) -- Distance (Miles) --

		OPTIMISTIC	NOMINAL	CONSERVATIVE
Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	28.92	32.13	35.34
Variable O&M	cents/kWh	1.12	1.24	1.37
Land Lease	$K	27	30	33
FIRST YEAR O&M	$K	500	545	579
Total O&M, cents/kWh		2.94	3.26	3.59

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Maui	Location:	Puunene	Project Code:	291, 292, 293
		Ownrshp:	State		

Capacity (MW)	10	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	400
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC		NOMINAL		CONSERVATIVE
ENERGY PRODUCTION						
Gross Energy (MWh/yr)		17,870		17,019		15,317
Expected Losses (%)		3.1%		3.3%		3.6%
Capacity Factor (net)		20.0%		19.1%		17.2%
Net Energy (MWh/yr)		17,252		16,430		14,787
CAPITAL COSTS	1995$					
Process Capital		$/kWe,net		$/kWe,net		$/kWe,net
Support Structure		391		435		478
Aximuth/Elevation Drives		115		128		140
Facets		151		168		184
Dish Control System		5		5		6
Stirling Engine/Generator		412		458		503
Installation		301		334		367
Overseas Shipping		30		34		37
Legal Fees & Permitting		0.5		0.5		0.6
General Facilities						
Grubbing & Grading		102		113		130
Roads, buildings, fence		48		53		58
Engineering & Overhead		96		101		106
Project Contingency		189		199		209
Initial Costs		9		10		10
TOTAL CAPITAL COSTS	$/kWe,net	1,849		2,037		2,231
	$K	18,192		20,044		21,951

TRANSMISSION

Size (kV)	--	Distance (Miles)	--		
Cost of Upgrade, $M			0	0	0

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	17.35	19.28	21.21
Variable O&M	cents/kWh	0.89	0.99	1.09
Land Lease	$K	27	30	33
FIRST YEAR O&M	$K	355	386	407
Total O&M, cents/kWh		1.93	2.15	2.36

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Maui	Location	Lower Paia	Project Code	679,680,681

Project size (MWe)	60	Stage (current/future)	future
Resource (kW/m, avg.)	13.7	Extent (no. x dia. buoys)	360 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	692,688	692,688	692,688
Wave energy absorbtion efficiency	52%	42%	21%
Absorbed energy (MWh/yr)	359,023	291,993	145,996
Conversion & sea-to-shore transmission efficiency	75%	78%	81%
Landed energy at 100% availability (MWh/yr)	269,353	226,638	117,689
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	255,885	203,974	94,151
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	35,430,000	53,145,000	70,860,000
Pelton turbine/generator	17,625,000	17,625,000	17,625,000
Balance of mechanical & electrical plant	6,712,000	6,712,000	6,712,000
Mooring hardware	8,961,000	8,961,000	8,961,000
Deployment	4,909,000	7,364,000	9,818,000
Sea-to-shore transmission	4,994,000	4,994,000	4,994,000
Onshore substation	3,172,000	3,172,000	3,172,000
Legal fees and permitting	795,000	845,000	896,000
Process Capital Sub-Total	82,598,000	102,818,000	123,038,000
General Facilities	4,130,000	10,282,000	18,456,000
Engineering & Overhead	8,260,000	10,282,000	12,304,000
Project Contingency	9,499,000	12,338,000	15,380,000
Initial Costs	2,310,000	3,224,000	4,389,000
TOTAL PLANT COST	106,797,000	138,943,000	173,566,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	3,000,000	4,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	1,652,000	4,113,000	7,382,000
Amortized periodic replacements	994,000	2,000,000	4,685,000
FIRST YEAR O&M COST	2,646,000	6,112,000	12,067,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Maui Location Lower Paia Project Code 676,677,678

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	13.7	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	346,344	346,344	346,344
Wave energy absorbtion efficiency	52%	42%	21%
Absorbed energy (MWh/yr)	179,512	145,996	72,998
Conversion & sea-to-shore transmission efficiency	75%	78%	81%
Landed energy at 100% availability (MWh/yr)	134,692	113,331	58,848
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	127,957	101,998	47,078
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,220,000	3,220,000	3,220,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	750,000
Process Capital Sub-Total	43,231,000	53,798,000	64,364,000
General Facilities	2,162,000	5,380,000	9,655,000
Engineering & Overhead	4,323,000	5,380,000	6,436,000
Project Contingency	4,972,000	6,456,000	8,046,000
Initial Costs	1,208,000	1,684,000	2,290,000
TOTAL PLANT COST	55,896,000	72,697,000	90,791,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	3,000,000	4,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	865,000	2,152,000	3,862,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,367,000	3,166,000	6,241,000

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Maui	Location	Lower Paia	Project Code	673,674,675

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	13.7	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	115,448	115,448	115,448
Wave energy absorbtion efficiency	52%	42%	21%
Absorbed energy (MWh/yr)	59,837	48,665	24,333
Conversion & sea-to-shore transmission efficiency	75%	78%	81%
Landed energy at 100% availability (MWh/yr)	44,879	37,763	19,612
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	42,635	33,987	15,690
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,715,000	1,715,000	1,715,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	631,000	641,000	651,000
Process Capital Sub-Total	16,665,000	20,796,000	24,927,000
General Facilities	833,000	2,080,000	3,739,000
Engineering & Overhead	1,667,000	2,080,000	2,493,000
Project Contingency	1,917,000	2,496,000	3,116,000
Initial Costs	464,000	648,000	880,000
TOTAL PLANT COST	21,546,000	28,099,000	35,155,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	333,000	832,000	1,496,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	508,000	1,188,000	2,337,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Maui Location Opana Point Project Code 688,689,690

Project size (MWe)	60	Stage (current/future)	future
Resource (kW/m, avg.)	14.4	Extent (no. x dia. buoys)	360 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	727,264	727,264	727,264
Wave energy absorbtion efficiency	52%	42%	21%
Absorbed energy (MWh/yr)	376,834	306,735	153,368
Conversion & sea-to-shore transmission efficiency	74%	77%	81%
Landed energy at 100% availability (MWh/yr)	279,768	235,538	123,603
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	265,780	211,984	98,882
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	35,430,000	53,145,000	70,860,000
Pelton turbine/generator	17,625,000	17,625,000	17,625,000
Balance of mechanical & electrical plant	6,712,000	6,712,000	6,712,000
Mooring hardware	8,961,000	8,961,000	8,961,000
Deployment	4,909,000	7,364,000	9,818,000
Sea-to-shore transmission	4,994,000	4,994,000	4,994,000
Onshore substation	3,172,000	3,172,000	3,172,000
Legal fees and permitting	795,000	845,000	896,000
Process Capital Sub-Total	82,598,000	102,818,000	123,038,000
General Facilities	4,130,000	10,282,000	18,456,000
Engineering & Overhead	8,260,000	10,282,000	12,304,000
Project Contingency	9,499,000	12,338,000	15,380,000
Initial Costs	2,310,000	3,224,000	4,389,000
TOTAL PLANT COST	106,797,000	138,943,000	173,566,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	3,000,000	4,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	1,652,000	4,113,000	7,382,000
Amortized periodic replacements	994,000	2,000,000	4,685,000
FIRST YEAR O&M COST	2,646,000	6,112,000	12,067,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Maui	Location	Opana Point	Project Code	685, 686, 687

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	14.4	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	363,632	363,632	363,632
Wave energy absorbtion efficiency	52%	42%	21%
Absorbed energy (MWh/yr)	188,417	153,368	76,684
Conversion & sea-to-shore transmission efficiency	74%	77%	81%
Landed energy at 100% availability (MWh/yr)	139,901	117,782	61,805
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	132,906	106,004	49,444
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,220,000	3,220,000	3,220,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	750,000
Process Capital Sub-Total	43,231,000	53,798,000	64,364,000
General Facilities	2,162,000	5,380,000	9,655,000
Engineering & Overhead	4,323,000	5,380,000	6,436,000
Project Contingency	4,972,000	6,456,000	8,046,000
Initial Costs	1,208,000	1,684,000	2,290,000
TOTAL PLANT COST	55,896,000	72,697,000	90,791,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	3,000,000	4,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	865,000	2,152,000	3,862,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,367,000	3,166,000	6,241,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Maui Location Opana Point Project Code 682,683,684

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	14.4	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	121,211	121,211	121,211
Wave energy absorbtion efficiency	52%	42%	21%
Absorbed energy (MWh/yr)	62,806	51,123	25,561
Conversion & sea-to-shore transmission efficiency	74%	77%	81%
Landed energy at 100% availability (MWh/yr)	46,614	39,246	20,597
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	44,283	35,321	16,478
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,715,000	1,715,000	1,715,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	631,000	641,000	651,000
Process Capital Sub-Total	16,665,000	20,796,000	24,927,000
General Facilities	833,000	2,080,000	3,739,000
Engineering & Overhead	1,667,000	2,080,000	2,493,000
Project Contingency	1,917,000	2,496,000	3,116,000
Initial Costs	464,000	648,000	880,000
TOTAL PLANT COST	21,546,000	28,099,000	35,155,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	333,000	832,000	1,496,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	508,000	1,188,000	2,337,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Maui	Location	Waiehu Point	Project Code	670,671,672

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	12.5	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	340,455	340,455	340,455
Wave energy absorbtion efficiency	52%	43%	21%
Absorbed energy (MWh/yr)	178,477	145,330	72,665
Conversion & sea-to-shore transmission efficiency	75%	77%	80%
Landed energy at 100% availability (MWh/yr)	133,565	112,507	58,443
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	126,887	101,256	46,754
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,549,000	3,549,000	3,549,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	698,000	724,000	750,000
Process Capital Sub-Total	43,561,000	54,128,000	64,694,000
General Facilities	2,178,000	5,413,000	9,704,000
Engineering & Overhead	4,356,000	5,413,000	6,469,000
Project Contingency	5,010,000	6,495,000	8,087,000
Initial Costs	1,217,000	1,694,000	2,301,000
TOTAL PLANT COST	56,322,000	73,142,000	91,255,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	3,000,000	4,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	871,000	2,165,000	3,882,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,374,000	3,179,000	6,261,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Maui Location Waiehu Point Project Code 667,668,669

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	13.5	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	113,485	113,485	113,485
Wave energy absorbtion efficiency	52%	43%	21%
Absorbed energy (MWh/yr)	59,492	48,443	24,222
Conversion & sea-to-shore transmission efficiency	75%	77%	80%
Landed energy at 100% availability (MWh/yr)	44,494	37,481	19,475
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	42,269	33,733	15,580
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,986,000	1,986,000	1,986,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	631,000	642,000	652,000
Process Capital Sub-Total	16,936,000	21,067,000	25,198,000
General Facilities	847,000	2,107,000	3,780,000
Engineering & Overhead	1,694,000	2,107,000	2,520,000
Project Contingency	1,948,000	2,528,000	3,150,000
Initial Costs	471,000	656,000	889,000
TOTAL PLANT COST	21,896,000	28,464,000	35,536,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	339,000	843,000	1,512,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	514,000	1,199,000	2,354,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui   Location McGregor Point   Project Code: 460.461.462 (leave blank)

Capacity (MW)	10	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	26,544	24,131	21,718
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	23,189	19,874	16,801
CAPITAL COSTS			
Process Capital			
Turbines & Towers	5,596,290	6,218,100	6,839,910
Foundations	436,590	441,000	445,410
Assembly & Checkout	258,420	261,030	263,640
Electrical Infrastructure	1,144,758	1,156,322	1,167,885
Sub-Station	550,686	556,248	561,810
Overseas Shipping	193,347	195,300	197,253
Legal Fees & Permitting	250,704	313,379	391,724
General Facilities			
Roads & Grading	101,871	102,900	103,929
Control System	88,066	88,956	89,846
Control Buildings	36,990	37,363	37,737
Central Building	85,121	94,579	118,223
Engineering & Overhead	874,284	946,518	1,021,737
Project Contingency	961,713	1,041,169	1,123,910
Initial Costs	497,902	514,925	538,237
SUB-TOTAL	$11,076,741	$11,967,789	$12,901,252
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	133,915	104,339	97,025
Fixed O&M	137,474	138,863	140,251
Land Lease	28,249	29,736	31,223
FIRST YEAR O&M	$299,638	$272,938	$268,499

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location McGregor Point Project Code: 463,464,465 (leave blank)

Capacity (MW)	10	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	32,870	29,882	26,894
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	28,715	24,611	20,805
CAPITAL COSTS			
Process Capital			
Turbines & Towers	4,898,573	5,442,858	6,259,287
Foundations	352,983	356,549	360,114
Assembly & Checkout	211,064	213,196	215,328
Electrical Infrastructure	1,116,197	1,127,471	1,138,746
Sub-Station	550,686	556,248	561,810
Overseas Shipping	159,511	161,123	162,734
Legal Fees & Permitting	248,681	310,851	388,564
General Facilities			
Roads & Grading	84,407	85,260	86,113
Control System	71,928	72,655	73,381
Control Buildings	30,211	30,516	30,822
Central Building	85,121	94,579	118,223
Engineering & Overhead	780,936	845,131	939,512
Project Contingency	859,030	929,644	1,033,463
Initial Costs	484,459	497,185	526,692
SUB-TOTAL	$9,933,787	$10,723,265	$11,894,790
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	162,514	126,622	117,745
Fixed O&M	134,724	136,085	137,446
Land Lease	28,967	30,492	32,017
FIRST YEAR O&M	$326,205	$293,199	$287,208

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location NW Haleakala Project Code: 478,479,480
(leave blank)

Capacity (MW)	50	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	200
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	114,352	103,956	93,561
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	88,001	74,804	62,645
CAPITAL COSTS			
Process Capital			
Turbines & Towers	27,421,821	30,468,690	33,515,559
Foundations	1,954,260	1,974,000	1,993,740
Assembly & Checkout	1,292,099	1,305,150	1,318,202
Electrical Infrastructure	4,292,844	4,336,206	4,379,568
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	966,735	976,500	986,265
Legal Fees & Permitting	318,296	397,870	497,338
General Facilities			
Roads & Grading	376,299	380,100	383,901
Control System	440,332	444,780	449,228
Control Buildings	184,948	186,816	188,684
Central Building	85,121	94,579	118,223
Engineering & Overhead	4,008,618	4,334,593	4,663,976
Project Contingency	4,409,480	4,768,052	5,130,374
Initial Costs	1,804,585	1,892,379	2,002,134
SUB-TOTAL	$50,308,866	$54,340,955	$58,436,243
TRANSMISSION			
Cost of Upgrade	$2,000,000	$3,000,000	$4,000,000
ANNUAL EXPENSES			
Variable O&M	508,208	392,718	361,776
Fixed O&M	687,369	694,313	701,256
Land Lease	423,738	446,040	468,342
FIRST YEAR O&M	$1,619,316	$1,533,071	$1,531,373

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location NW Haleakala Project Code: 481,482,483
(leave blank)

Capacity (MW)	50	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	166
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	142,463	129,512	116,561
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	109,635	93,192	78,045
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,148,478	26,831,642	30,856,389
Foundations	1,589,595	1,605,652	1,621,708
Assembly & Checkout	1,061,717	1,072,442	1,083,166
Electrical Infrastructure	4,211,105	4,253,642	4,296,178
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	802,390	810,495	818,600
Legal Fees & Permitting	308,969	386,211	482,764
General Facilities			
Roads & Grading	312,682	315,840	318,998
Control System	361,821	365,476	369,130
Control Buildings	151,972	153,507	155,042
Central Building	85,121	94,579	118,223
Engineering & Overhead	3,578,728	3,867,072	4,292,925
Project Contingency	3,936,601	4,253,780	4,722,218
Initial Costs	1,705,283	1,774,096	1,915,409
SUB-TOTAL	$45,007,889	$48,565,674	$53,859,803
TRANSMISSION			
Cost of Upgrade	$2,000,000	$3,000,000	$4,000,000
ANNUAL EXPENSES			
Variable O&M	620,478	479,475	441,697
Fixed O&M	673,622	680,426	687,231
Land Lease	437,144	460,152	483,160
FIRST YEAR O&M	$1,731,245	$1,620,053	$1,612,087

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui   Location NW Haleakala   Project Code: 472,473,474
(leave blank)

Capacity (MW)	30	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	120
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	68,611	62,374	56,136
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	52,801	44,882	37,587
CAPITAL COSTS			
Process Capital			
Turbines & Towers	16,788,870	18,654,300	20,519,730
Foundations	1,172,556	1,184,400	1,196,244
Assembly & Checkout	775,259	783,090	790,921
Electrical Infrastructure	2,575,706	2,601,724	2,627,741
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	580,041	585,900	591,759
Legal Fees & Permitting	284,761	355,951	444,939
General Facilities			
Roads & Grading	226,611	228,900	231,189
Control System	264,199	266,868	269,537
Control Buildings	110,969	112,090	113,210
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,451,615	2,653,655	2,858,893
Project Contingency	2,696,777	2,919,020	3,144,782
Initial Costs	1,159,529	1,214,141	1,282,208
SUB-TOTAL	$30,824,071	$33,323,361	$35,874,807
TRANSMISSION			
Cost of Upgrade	$2,000,000	$3,000,000	$4,000,000
ANNUAL EXPENSES			
Variable O&M	304,925	235,631	217,065
Fixed O&M	412,422	416,588	420,753
Land Lease	254,243	267,624	281,005
FIRST YEAR O&M	$971,589	$919,843	$918,824

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location NW Haleakala Project Code: 475,476,477
(leave blank)

Capacity (MW)	30	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	100
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	85,821	78,019	70,217
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	66,045	56,140	47,015
CAPITAL COSTS			
Process Capital			
Turbines & Towers	14,844,159	16,493,510	18,967,537
Foundations	957,587	967,260	976,933
Assembly & Checkout	639,589	646,049	652,510
Electrical Infrastructure	2,536,810	2,562,435	2,588,059
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	483,368	488,250	493,133
Legal Fees & Permitting	279,249	349,061	436,327
General Facilities			
Roads & Grading	189,189	191,100	193,011
Control System	217,964	220,166	222,368
Control Buildings	91,549	92,474	93,399
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,197,664	2,377,363	2,642,693
Project Contingency	2,417,431	2,615,099	2,906,962
Initial Costs	1,105,535	1,148,766	1,236,512
SUB-TOTAL	$27,697,273	$29,914,856	$33,213,097
TRANSMISSION			
Cost of Upgrade	$2,000,000	$3,000,000	$4,000,000
ANNUAL EXPENSES			
Variable O&M	373,782	288,840	266,082
Fixed O&M	404,173	408,256	412,338
Land Lease	263,340	277,200	291,060
FIRST YEAR O&M	$1,041,295	$974,296	$969,481

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location NW Haleakala Project Code: 466,467,468
(leave blank)

Capacity (MW)	10	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,870	20,791	18,712
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	19,980	17,124	14,476
CAPITAL COSTS			
Process Capital			
Turbines & Towers	5,596,290	6,218,100	6,839,910
Foundations	390,852	394,800	398,748
Assembly & Checkout	258,420	261,030	263,640
Electrical Infrastructure	858,569	867,241	875,914
Sub-Station	550,686	556,248	561,810
Overseas Shipping	193,347	195,300	197,253
Legal Fees & Permitting	249,983	312,478	390,598
General Facilities			
Roads & Grading	76,923	77,700	78,477
Control System	88,066	88,956	89,846
Control Buildings	36,990	37,363	37,737
Central Building	85,121	94,579	118,223
Engineering & Overhead	838,525	910,380	985,216
Project Contingency	922,377	1,001,417	1,083,737
Initial Costs	498,739	517,438	541,653
SUB-TOTAL	$10,644,886	$11,533,030	$12,462,762
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	115,382	89,899	83,597
Fixed O&M	137,474	138,863	140,251
Land Lease	84,748	89,208	93,668
FIRST YEAR O&M	$337,604	$317,970	$317,517

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location NW Haleakala Project Code: 469,470,471
(leave blank)

Capacity (MW)	10	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	28,321	25,746	23,172
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	24,741	21,205	17,926
CAPITAL COSTS			
Process Capital			
Turbines & Towers	4,898,573	5,442,858	6,259,287
Foundations	316,004	319,196	322,388
Assembly & Checkout	211,064	213,196	215,328
Electrical Infrastructure	837,147	845,603	854,060
Sub-Station	550,686	556,248	561,810
Overseas Shipping	159,511	161,123	162,734
Legal Fees & Permitting	248,001	310,001	387,501
General Facilities			
Roads & Grading	63,825	64,470	65,115
Control System	71,928	72,655	73,381
Control Buildings	30,211	30,516	30,822
Central Building	85,121	94,579	118,223
Engineering & Overhead	747,207	811,045	905,065
Project Contingency	821,928	892,149	995,571
Initial Costs	485,157	499,801	530,290
SUB-TOTAL	$9,526,364	$10,313,440	$11,481,576
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	140,023	109,098	101,450
Fixed O&M	134,724	136,085	137,446
Land Lease	86,902	91,476	96,050
FIRST YEAR O&M	$361,650	$336,659	$334,946

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location Puunene Project Code: 490,491,492 (leave blank)

Capacity (MW)	30	Stage (current/future)	Current
Resource (mph, avg.)	13.6	Extent (# of units)	120
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	55,135	50,123	45,110
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	42,430	36,067	30,204
CAPITAL COSTS			
Process Capital			
Turbines & Towers	16,788,870	18,654,300	20,519,730
Foundations	1,309,770	1,323,000	1,336,230
Assembly & Checkout	775,259	783,090	790,921
Electrical Infrastructure	2,575,706	2,601;724	2,627,741
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	580,041	585,900	591,759
Legal Fees & Permitting	285,038	356,298	445,372
General Facilities			
Roads & Grading	226,611	228,900	231,189
Control System	264,199	266,868	269,537
Control Buildings	110,969	112,090	113,210
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,465,364	2,667,549	2,872,934
Project Contingency	2,711,901	2,934,304	3,160,228
Initial Costs	1,105,510	1,161,329	1,228,113
SUB-TOTAL	$30,936,416	$33,438,674	$35,990,620
TRANSMISSION			
Cost of Upgrade	$2,000,000	$3,000,000	$4,000,000
ANNUAL EXPENSES			
Variable O&M	245,033	189,350	174,430
Fixed O&M	412,422	416,588	420,753
Land Lease	84,748	89,208	93,668
FIRST YEAR O&M	$742,202	$695,145	$688,852

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location Puunene Project Code: 493,494,495
(leave blank)

Capacity (MW)	30	Stage (current/future)	Future
Resource (mph, avg.)	13.6	Extent (# of units)	100
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	68,965	62,695	56,426
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	53,073	45,113	37,781
CAPITAL COSTS			
Process Capital			
Turbines & Towers	14,844,159	16,493,510	18,967,537
Foundations	1,069,646	1,080,450	1,091,255
Assembly & Checkout	639,589	646,049	652,510
Electrical Infrastructure	2,536,810	2,562,435	2,588,059
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	483,368	488,250	493,133
Legal Fees & Permitting	279,476	349,344	436,680
General Facilities			
Roads & Grading	189,189	191,100	193,011
Control System	217,964	220,166	222,368
Control Buildings	91,549	92,474	93,399
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,208,893	2,388,710	2,654,161
Project Contingency	2,429,782	2,627,581	2,919,577
Initial Costs	1,046,008	1,091,129	1,177,712
SUB-TOTAL	$27,773,610	$29,994,522	$33,293,054
TRANSMISSION			
Cost of Upgrade	$3,000,000	$3,000,000	$3,000,000
ANNUAL EXPENSES			
Variable O&M	300,366	232,108	213,820
Fixed O&M	404,173	408,256	412,338
Land Lease	87,780	92,400	97,020
FIRST YEAR O&M	$792,319	$732,764	$723,178

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location Puunene Project Code: 484,485,486 (leave blank)

Capacity (MW)	10	Stage (current/future)	Current
Resource (mph, avg.)	13.6	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	18,378	16,708	15,037
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	14,940	12,746	10,720
CAPITAL COSTS			
Process Capital			
Turbines & Towers	5,596,290	6,218,100	6,839,910
Foundations	436,590	441,000	445,410
Assembly & Checkout	258,420	261,030	263,640
Electrical Infrastructure	858,569	867,241	875,914
Sub-Station	550,686	556,248	561,810
Overseas Shipping	193,347	195,300	197,253
Legal Fees & Permitting	250,075	312,594	390,742
General Facilities			
Roads & Grading	76,923	77,700	78,477
Control System	88,066	88,956	89,846
Control Buildings	36,990	37,363	37,737
Central Building	85,121	94,579	118,223
Engineering & Overhead	843,108	915,011	989,896
Project Contingency	927,418	1,006,512	1,088,886
Initial Costs	478,448	497,945	521,752
SUB-TOTAL	$10,680,050	$11,569,580	$12,499,496
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	86,278	66,919	61,908
Fixed O&M	137,474	138,863	140,251
Land Lease	28,249	29,736	31,223
FIRST YEAR O&M	$252,001	$235,517	$233,382

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location Puunene Project Code: 487,488,489 (leave blank)

Capacity (MW)	10	Stage (current/future)	Future
Resource (mph, avg.)	13.6	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,758	20,689	18,620
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	18,501	15,784	13,275
CAPITAL COSTS			
Process Capital			
Turbines & Towers	4,898,573	5,442,858	6,259,287
Foundations	352,983	356,549	360,114
Assembly & Checkout	211,064	213,196	215,328
Electrical Infrastructure	837,147	845,603	854,060
Sub-Station	550,686	556,248	561,810
Overseas Shipping	159,511	161,123	162,734
Legal Fees & Permitting	248,076	310,094	387,618
General Facilities			
Roads & Grading	63,825	64,470	65,115
Control System	71,928	72,655	73,381
Control Buildings	30,211	30,516	30,822
Central Building	85,121	94,579	118,223
Engineering & Overhead	750,913	814,789	908,849
Project Contingency	826,004	896,268	999,734
Initial Costs	462,741	478,489	508,617
SUB-TOTAL	$9,548,782	$10,337,438	$11,505,693
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	104,704	81,210	75,129
Fixed O&M	134,724	136,085	137,446
Land Lease	28,967	30,492	32,017
FIRST YEAR O&M	$268,396	$247,787	$244,591

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location West Maui Project Code: S08, S09, S10
(leave blank)

Capacity (MW)	50	Stage (current/future)	Current
Resource (mph, avg.)	14.4	Extent (# of units)	200
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	89,747	81,588	73,429
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	72,957	62,245	52,349
CAPITAL COSTS			
Process Capital			
Turbines & Towers	27,421,821	30,468,690	33,515,559
Foundations	1,954,260	1,974,000	1,993,740
Assembly & Checkout	1,292,099	1,305,150	1,318,202
Electrical Infrastructure	5,151,413	5,203,447	5,255,482
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	966,735	976,500	986,265
Legal Fees & Permitting	320,182	400,227	500,284
General Facilities			
Roads & Grading	451,143	455,700	460,257
Control System	440,332	444,780	449,228
Control Buildings	184,948	186,816	188,684
Central Building	85,121	94,579	118,223
Engineering & Overhead	4,102,148	4,429,113	4,759,498
Project Contingency	4,512,363	4,872,024	5,235,447
Initial Costs	1,805,498	1,898,769	2,010,384
SUB-TOTAL	$51,441,490	$55,491,035	$59,600,306
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	421,324	326,785	302,314
Fixed O&M	687,369	694,313	701,256
Land Lease	423,738	446,040	468,342
FIRST YEAR O&M	$1,532,432	$1,467,137	$1,471,912

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location West Maui Project Code: S11,S12,S13
(leave blank)

Capacity (MW)	50	Stage (current/future)	Future
Resource (mph, avg.)	14.4	Extent (# of units)	166
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	111,810	101,645	91,481
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	90,891	77,546	65,218
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,148,478	26,831,642	30,856,389
Foundations	1,589,595	1,605,652	1,621,708
Assembly & Checkout	1,061,717	1,072,442	1,083,166
Electrical Infrastructure	5,053,326	5,104,370	5,155,414
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	802,390	810,495	818,600
Legal Fees & Permitting	310,796	388,495	485,619
General Facilities			
Roads & Grading	374,802	378,588	382,374
Control System	361,821	365,476	369,130
Control Buildings	151,972	153,507	155,042
Central Building	85,121	94,579	118,223
Engineering & Overhead	3,669,345	3,958,649	4,385,472
Project Contingency	4,036,279	4,354,513	4,824,019
Initial Costs	1,700,693	1,776,133	1,919,656
SUB-TOTAL	$46,099,763	$49,675,780	$54,983,864
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	514,400	398,976	369,100
Fixed O&M	673,622	680,426	687,231
Land Lease	437,144	460,152	483,160
FIRST YEAR O&M	$1,625,167	$1,539,554	$1,539,490

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location West Maui Project Code: SD2,SD3,SD4
(leave blank)

Capacity (MW)	30	Stage (current/future)	Current
Resource (mph, avg.)	14.4	Extent (# of units)	120
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	53,848	48,953	44,058
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	43,774	37,347	31,409
CAPITAL COSTS			
Process Capital			
Turbines & Towers	16,788,870	18,654,300	20,519,730
Foundations	1,172,556	1,184,400	1,196,244
Assembly & Checkout	775,259	783,090	790,921
Electrical Infrastructure	3,090,848	3,122,068	3,153,289
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	580,041	585,900	591,759
Legal Fees & Permitting	285,893	357,366	446,707
General Facilities			
Roads & Grading	271,517	274,260	277,003
Control System	264,199	266,868	269,537
Control Buildings	110,969	112,090	113,210
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,507,733	2,710,366	2,916,205
Project Contingency	2,758,506	2,981,403	3,207,826
Initial Costs	1,160,077	1,217,975	1,287,158
SUB-TOTAL	$31,503,646	$34,013,409	$36,573,245
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	252,795	196,071	181,389
Fixed O&M	412,422	416,588	420,753
Land Lease	254,243	267,624	281,005
FIRST YEAR O&M	$919,459	$880,282	$883,147

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location West Maui Project Code: 505,506,507 (leave blank)

Capacity (MW)	30	Stage (current/future)	Future
Resource (mph, avg.)	14.4	Extent (# of units)	100
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	67,355	61,232	55,109
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	54,754	46,715	39,288
CAPITAL COSTS			
Process Capital			
Turbines & Towers	14,844,159	16,493,510	18,967,537
Foundations	957,587	967,260	976,933
Assembly & Checkout	639,589	646,049	652,510
Electrical Infrastructure	3,044,172	3,074,922	3,105,671
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	483,368	488,250	493,133
Legal Fees & Permitting	280,350	350,437	438,046
General Facilities			
Roads & Grading	226,611	228,900	231,189
Control System	217,964	220,166	222,368
Control Buildings	91,549	92,474	93,399
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,252,253	2,432,529	2,698,444
Project Contingency	2,477,478	2,675,782	2,968,288
Initial Costs	1,102,770	1,149,993	1,239,071
SUB-TOTAL	$28,355,028	$30,583,595	$33,890,242
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	309,880	240,347	222,349
Fixed O&M	404,173	408,256	412,338
Land Lease	263,340	277,200	291,060
FIRST YEAR O&M	$977,393	$925,803	$925,747

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location West Maui Project Code: 496,497,498
(leave blank)

Capacity (MW)	10	Stage (current/future)	Current
Resource (mph, avg.)	14.4	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	17,949	16,318	14,686
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	14,591	12,449	10,470
CAPITAL COSTS			
Process Capital			
Turbines & Towers	5,596,290	6,218,100	6,839,910
Foundations	390,852	394,800	398,748
Assembly & Checkout	258,420	261,030	263,640
Electrical Infrastructure	1,030,283	1,040,689	1,051,096
Sub-Station	550,686	556,248	561,810
Overseas Shipping	193,347	195,300	197,253
Legal Fees & Permitting	250,360	312,950	391,187
General Facilities			
Roads & Grading	91,892	92,820	93,748
Control System	88,066	88,956	89,846
Control Buildings	36,990	37,363	37,737
Central Building	85,121	94,579	118,223
Engineering & Overhead	857,231	929,284	1,004,320
Project Contingency	942,954	1,022,212	1,104,752
Initial Costs	495,487	515,877	540,493
SUB-TOTAL	$10,867,976	$11,760,207	$12,692,764
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	84,265	65,357	60,463
Fixed O&M	137,474	138,863	140,251
Land Lease	84,748	89,208	93,668
FIRST YEAR O&M	$306,486	$293,427	$294,382

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Maui Location West Maui Project Code: 499,500,501
(leave blank)

Capacity (MW)	10	Stage (current/future)	Future
Resource (mph, avg.)	14.4	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,227	20,207	18,186
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	18,069	15,416	12,965
CAPITAL COSTS			
Process Capital			
Turbines & Towers	4,898,573	5,442,858	6,259,287
Foundations	316,004	319,196	322,388
Assembly & Checkout	211,064	213,196	215,328
Electrical Infrastructure	1,004,577	1,014,724	1,024,871
Sub-Station	550,686	556,248	561,810
Overseas Shipping	159,511	161,123	162,734
Legal Fees & Permitting	248,364	310,455	388,069
General Facilities			
Roads & Grading	76,175	76,944	77,713
Control System	71,928	72,655	73,381
Control Buildings	30,211	30,516	30,822
Central Building	85,121	94,579	118,223
Engineering & Overhead	765,221	829,249	923,463
Project Contingency	841,743	912,174	1,015,809
Initial Costs	480,076	496,761	527,724
SUB-TOTAL	$9,739,254	$10,530,679	$11,701,623
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	102,260	79,315	73,375
Fixed O&M	134,724	136,085	137,446
Land Lease	86,902	91,476	96,050
FIRST YEAR O&M	$323,887	$306,876	$306,871

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Organic Wastes - Ethanol

Island: Oahu Location: Barber's Point Project Code: 186, 187, 188

Capacity (MW)	70	Stage (current/future):	future
Resource (fresh tons/year):	418,060	Extent:	N/A
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (eq. MWh/yr)	475,416	432,196	388,977
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	475,416	432,196	388,977
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	2,414,592	3,018,240	3,621,888
Biomass preparation	3,888,024	4,860,030	5,832,036
Pretreatment	12,347,089	15,433,862	18,520,634
Hexose fermentation	12,107,926	15,134,907	18,161,889
Pentose fermentation	3,376,300	4,220,375	5,064,450
Distillation & dehydration	2,114,766	2,643,458	3,172,149
Product storage & denature	1,705,387	2,131,734	2,558,081
Boiler	10,782,830	13,478,538	16,174,245
Non-boiler utilities	18,077,319	22,596,649	27,115,979
Environmental	2,234,348	2,792,935	3,351,522
Miscellaneous & control	3,461,408	4,326,760	5,192,112
Emzyme production	1,466,224	1,832,779	2,199,335
Legal fee & Permitting	650,904	813,630	976,356
General Facilities			
Engineering & overhead	7,462,712	9,328,390	11,194,068
Project contingency	8,208,983	10,261,229	12,313,474
Initial cost	1,277,505	1,596,881	1,916,257
SUB-TOTAL	91,576,318	114,470,398	137,364,476

TRANSMISSION

Size (kV):	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	(5,346,689)	(2,502,761)	341,167
Fixed O&M ($)	11,546,833	14,433,541	17,320,250
Land Lease	9,600	12,000	14,400
FIRST YEAR O&M	6,209,744	11,942,780	17,675,817

Note: 1 MW = 0.355 MGPY ethanol
70 MW = 25 MGPY ethanol

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Organic Wastes - Methanol

Island: Oahu | Location: Barber's Point | Project Code: 216, 217, 218

Capacity (MW):	95	Stage (current/future):	future
Resource (dry tons/year):	520,833	Extent (harvested acres/year):	N/A
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (eq. MWh/yr)	639,477	581,342	523,208
Expected Losses (%)	0	0	0
Net Energy (eq. MWh/yr)	639,477	581,342	523,208
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	28,117,881	35,147,351	42,176,821
Feed handling, preparation	8,971,907	11,214,883	13,457,860
Gasification	3,494,321	4,367,902	5,241,482
Gas conditioning	5,645,480	7,056,850	8,468,221
Compression	11,269,974	14,087,467	16,904,961
Acid gas removal/cooling	5,131,301	6,414,126	7,696,951
MeOH syn/purification	14,208,142	17,760,178	21,312,213
Utilities/auxiliary	12,172,411	15,215,514	18,258,617
Legal fees & permitting	624,234	780,292	936,351
General Facilities			
Engineering & overhead	8,963,565	11,204,456	13,445,348
Project contingency	9,859,922	12,324,902	14,789,882
Initial cost	802,719	1,003,398	1,204,078
SUB-TOTAL	109,261,857	136,577,319	163,892,785

TRANSMISSION			
Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	(7,371,282)	(4,005,772)	(640,262)
Fixed O&M ($)	6,598,701	8,248,377	9,898,052
Land Lease	9,600	12,000	14,400
FIRST YEAR O&M	(762,981)	4,254,605	9,272,190

Note: 1MW = 0.5274 MGPY MeOH
95 MW = 50 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Organic Wastes - Electricity

Island: Oahu | Location: Barber's Point | Project Code: 219,220,221

Capacity (MW electricity):	50	Stage (current/future):	future
Resource (dry tons/year):	373,902	Extent (harvested acres/year):	N/A
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	22,328,576	27,910,719	33,492,863
Feed handling and prep.	8,370,725	10,463,407	12,556,088
Gasification & compressor/precooler	14,769,967	18,462,459	22,154,951
Physical cleanup	904,943	1,131,179	1,357,415
Ash handling	872,624	1,090,780	1,308,936
Gas turbine	19,617,878	24,522,347	29,426,816
Balance of plant	11,139,421	13,924,276	16,709,131
Legal fees & permitting	611,189	763,986	916,783
General Facilities			
Engineering & overhead	7,861,532	9,826,915	11,792,298
Project contingency	8,647,685	10,809,607	12,971,528
Initial cost	759,798	949,748	1,139,698
SUB-TOTAL	95,884,338	119,855,423	143,826,507

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	(5,814,218)	(3,528,753)	(1,243,268)
Fixed O&M ($)	3,318,969	4,148,712	4,978,454
Land Lease	9,600	12,000	14,400
FIRST YEAR O&M	(2,485,649)	631,959	3,749,586

PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Oahu   Location: Waialua   Project Code: 724,725,726

Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons/year):	127,750	Extent (harvested acres/year):	5,800
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	6,142,154	7,226,064	8,309,973
Gasification & compressor/precooler	843,041	991,813	1,140,585
Physical cleanup	17,235,500	20,277,059	23,318,618
Ash handling	321,158	377,833	434,508
Gas turbine	334,540	393,576	452,613
Balance of plant	6,490,076	7,635,383	8,780,691
Lega fee & permitting	579,916	682,254	784,592
General Facilities			
Engineering & overhead	3,194,639	3,758,398	4,322,158
Project contingency	3,514,102	4,134,238	4,754,374
Initial cost	1,869,387	2,199,279	2,529,171
SUB-TOTAL	40,524,513	47,675,897	54,827,283

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	8,795,067	10,347,137	11,899,207
Fixed O&M ($)	3,282,400	3,861,647	4,440,894
Land Lease	248,664	292,545	336,427
FIRST YEAR O&M	12,326,131	14,501,329	16,676,528

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Oahu | Location: Waialua | Project Code: 727, 728, 729

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	106,500	Extent (harvested acres/year):	5,000
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Lega fee & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,360,521	4,200,651	5,040,781
Initial cost	1,650,863	2,063,578	2,476,294
SUB-TOTAL	38,616,590	48,270,737	57,924,883

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	7,239,568	9,049,460	10,859,352
Fixed O&M ($)	2,915,397	3,644,246	4,373,095
Land Lease	196,812	246,015	295,218
FIRST YEAR O&M	10,351,777	12,939,721	15,527,665

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: OTEC (closed cycle, ammonia)

Island Oahu Location Kahe Point Project Code 249, 250, 251

Project size ($MWe_{gross\ summer}$)	60	Stage (current/future)	future
Resource (ΔT, summer)	23.1°C	CWP length, intake depth	3670m, 670m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Gross energy at constant summer ΔT (MWh/yr)	525,600	525,600	525,600
Seasonal ΔT variability factor	84%	84%	84%
Annual gross energy (MWh/yr)	441,504	441,504	441,504
Parasitic power losses	12 MWe	13 MWe	14 MWe
Net energy at 100% availability (MWh/yr)	353,203	345,845	338,486
Annual average availability	95%	90%	80%
NET ENERGY (MWh/yr)	335,543	311,260	270,789
CAPITAL COSTS ($)			
Plant structure	84,600,000	82,837,000	148,097,000
Seawater systems (pipelines and SW pumps)	95,880,000	132,540,000	233,496,000
Heat exchangers	67,680,000	138,062,000	92,966,000
Turbine/generators	56,400,000	66,270,000	11,891,000
Balance of plant	33,840,000	33,135,000	59,995,000
Substation	2,538,000	2,485,000	2,432,000
Legal fees and permitting	1,443,000	1,729,000	1,963,000
Process Capital Sub-Total	342,381,000	457,059,000	550,840,000
General Facilities	17,119,000	45,706,000	82,626,000
Engineering & Overhead	34,238,000	45,706,000	55,084,000
Project Contingency	39,374,000	54,847,000	68,855,000
Initial Costs	8,919,000	12,523,000	15,837,000
TOTAL PLANT COST	442,031,000	615,841,000	773,242,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	3,081,000	5,485,000	8,263,000
Amortized periodic replacements	0	0	0
FIRST YEAR O&M COST	3,081,000	5,485,000	8,263,00

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu Location: Lualualei Project Code: 97, 98, 99

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	111,749	97,192	87,499
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**110,654**	**96,220**	**86,598**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$22,206,250	$23,375,000	$24,543,750
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$804,021	$1,005,026	$1,256,283
General Facilities			
Roads and Grading	$2,944,148	$3,271,275	$3,598,403
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$14,961,240	$14,961,240	$14,961,240
Project Contingency	$17,474,884	$17,474,884	$17,474,884
Initial Costs	$3,767,583	$3,767,583	$3,767,583
SUB-TOTAL	**$207,007,475**	**$226,829,338**	**$236,013,952**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$137,832	$153,147	$168,462
Fixed O&M	$123,500	$130,000	$136,500
Land Lease	$41,921	$44,127	$46,333
FIRST YEAR O&M	**$303,253**	**$327,274**	**$351,295**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: Lualualei Project Code: 640, 641, 642

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	125,158	108,855	97,999
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**123,931**	**107,766**	**96,990**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$33,309,375	$35,062,500	$36,815,625
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$804,021	$1,005,026	$1,256,283
General Facilities			
Roads and Grading	$2,944,148	$3,271,275	$3,598,403
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$14,961,240	$14,961,240	$14,961,240
Project Contingency	$17,474,884	$17,474,884	$17,474,884
Initial Costs	$3,767,583	$3,767,583	$3,767,583
SUB-TOTAL	**$218,110,600**	**$238,516,838**	**$248,285,827**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$206,748	$229,721	$252,693
Fixed O&M	$154,375	$162,500	$170,625
Land Lease	$41,921	$44,127	$46,333
FIRST YEAR O&M	**$403,044**	**$436,348**	**$469,651**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Lualualei   Project Code: 100, 101, 102

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	115,801	100,717	85,636
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**114,666**	**99,710**	**84,754**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$15,988,500	$16,830,000	$17,671,500
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$691,226	$864,033	$1,080,041
General Facilities			
Roads and Grading	$2,355,318	$2,617,020	$2,878,722
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$9,916,283	$9,916,283	$9,916,283
Project Contingency	$12,177,875	$12,177,875	$12,177,875
Initial Costs	$2,634,678	$2,634,678	$2,634,678
SUB-TOTAL	**$145,330,451**	**$158,081,675**	**$164,491,726**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$129,084	$143,427	$157,770
Fixed O&M	$117,031	$123,191	$129,351
Land Lease	$33,196	$34,943	$36,690
FIRST YEAR O&M	**$279,312**	**$301,561**	**$323,810**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu   Location: Lualualei   Project Code: 643, 644, 645

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	129,698	112,803	95,912
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**128,426**	**111,675**	**94,924**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$23,982,750	$25,245,000	$26,507,250
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$691,226	$864,033	$1,080,041
General Facilities			
Roads and Grading	$2,355,318	$2,617,020	$2,878,722
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$9,916,283	$9,916,283	$9,916,283
Project Contingency	$12,177,875	$12,177,875	$12,177,875
Initial Costs	$2,634,678	$2,634,678	$2,634,678
SUB-TOTAL	**$153,324,701**	**$166,496,675**	**$173,327,476**
TRANSMISSION			
Cost of Upgrade	**$2,000,000**	**$2,000,000**	**$2,000,000**
ANNUAL EXPENSES			
Variable O&M	$193,626	$215,141	$236,655
Fixed O&M	$146,289	$153,989	$161,688
Land Lease	$33,196	$34,943	$36,690
FIRST YEAR O&M	**$373,112**	**$404,072**	**$435,033**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Lualualei   Project Code: 91, 92, 93

Capacity (MW)	20	Stage (current/future)	current
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	193,600
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	44,699	38,877	35,000
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**44,261**	**38,488**	**34,639**
CAPITAL COSTS			
Process Capital			
PV Modules	$51,840,000	$57,600,000	$60,480,000
Array Structure & Foundations	$9,405,000	$9,900,000	$10,395,000
Power Condtioning Units	$4,387,500	$6,750,000	$7,087,500
Electrical & SCADA	$7,449,273	$7,524,518	$7,599,763
Substation	$951,184	$1,001,246	$1,051,308
Overseas Shipping	$613,700	$646,000	$678,300
Legal Fees & Permitting	$598,843	$748,554	$935,693
General Facilities			
Roads and Grading	$1,202,985	$1,336,650	$1,470,315
Buildings and Fencing	$230,007	$255,563	$281,119
Engineering & Overhead	$6,733,626	$6,733,626	$6,733,626
Project Contingency	$7,862,173	$7,862,173	$7,862,173
Initial Costs	$1,696,482	$1,696,482	$1,696,482
SUB-TOTAL	**$92,970,772**	**$102,054,812**	**$106,271,279**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$55,133	$61,259	$67,385
Fixed O&M	$74,100	$78,000	$81,900
Land Lease	$16,768	$17,651	$18,534
FIRST YEAR O&M	**$146,002**	**$156,910**	**$167,818**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: Lualualei Project Code: 634, 635, 636

Capacity (MW)	20	Stage (current/future)	current
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	193,600
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	50,063	43,542	39,200
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**49,573**	**43,107**	**38,796**
CAPITAL COSTS			
Process Capital			
PV Modules	$51,840,000	$57,600,000	$60,480,000
Array Structure & Foundations	$14,107,500	$14,850,000	$15,592,500
Power Condtioning Units	$4,387,500	$6,750,000	$7,087,500
Electrical & SCADA	$7,449,273	$7,524,518	$7,599,763
Substation	$951,184	$1,001,246	$1,051,308
Overseas Shipping	$613,700	$646,000	$678,300
Legal Fees & Permitting	$598,843	$748,554	$935,693
General Facilities			
Roads and Grading	$1,202,985	$1,336,650	$1,470,315
Buildings and Fencing	$230,007	$255,563	$281,119
Engineering & Overhead	$6,733,626	$6,733,626	$6,733,626
Project Contingency	$7,862,173	$7,862,173	$7,862,173
Initial Costs	$1,696,482	$1,696,482	$1,696,482
SUB-TOTAL	**$97,673,272**	**$107,004,812**	**$111,468,779**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$82,700	$91,889	$101,077
Fixed O&M	$92,625	$97,500	$102,375
Land Lease	$16,768	$17,651	$18,534
FIRST YEAR O&M	**$192,093**	**$207,040**	**$221,986**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Lualualei   Project Code: 94, 95, 96

Capacity (MW)	20	Stage (current/future)	future
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	153,280
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	46,321	40,287	34,254
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**45,867**	**39,884**	**33,901**
CAPITAL COSTS			
Process Capital			
PV Modules	$36,288,000	$40,320,000	$42,336,000
Array Structure & Foundations	$6,771,600	$7,128,000	$7,484,400
Power Condtioning Units	$1,974,375	$3,037,500	$3,189,375
Electrical & SCADA	$5,873,752	$5,933,083	$5,992,414
Substation	$951,184	$1,001,246	$1,051,308
Overseas Shipping	$552,330	$581,400	$610,470
Legal Fees & Permitting	$548,002	$685,003	$856,254
General Facilities			
Roads and Grading	$962,388	$1,069,320	$1,176,252
Buildings and Fencing	$165,862	$184,291	$202,720
Engineering & Overhead	$4,460,154	$4,460,154	$4,460,154
Project Contingency	$5,474,000	$5,474,000	$5,474,000
Initial Costs	$1,185,830	$1,185,830	$1,185,830
SUB-TOTAL	**$65,207,477**	**$71,059,827**	**$74,019,177**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$51,634	$57,371	$63,108
Fixed O&M	$70,219	$73,915	$77,611
Land Lease	$13,278	$13,977	$14,676
FIRST YEAR O&M	**$135,131**	**$145,263**	**$155,395**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: Lualualei Project Code: 637, 638, 639

Capacity (MW)	20	Stage (current/future)	future
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	153,280
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	51,879	45,121	38,365
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**51,371**	**44,670**	**37,970**
CAPITAL COSTS			
Process Capital			
PV Modules	$36,288,000	$40,320,000	$42,336,000
Array Structure & Foundations	$10,157,400	$10,692,000	$11,226,600
Power Condtioning Units	$1,974,375	$3,037,500	$3,189,375
Electrical & SCADA	$5,873,752	$5,933,083	$5,992,414
Substation	$951,184	$1,001,246	$1,051,308
Overseas Shipping	$552,330	$581,400	$610,470
Legal Fees & Permitting	$548,002	$685,003	$856,254
General Facilities			
Roads and Grading	$962,388	$1,069,320	$1,176,252
Buildings and Fencing	$165,862	$184,291	$202,720
Engineering & Overhead	$4,460,154	$4,460,154	$4,460,154
Project Contingency	$5,474,000	$5,474,000	$5,474,000
Initial Costs	$1,185,830	$1,185,830	$1,185,830
SUB-TOTAL	**$68,593,277**	**$74,623,827**	**$77,761,377**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$77,451	$86,057	$94,662
Fixed O&M	$87,774	$92,394	$97,013
Land Lease	$13,278	$13,977	$14,676
FIRST YEAR O&M	**$178,503**	**$192,427**	**$206,351**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Lualualei   Project Code: 85, 86, 87

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,350	19,438	17,500
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,131**	**19,244**	**17,320**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$710,031	$710,031	$710,031
SUB-TOTAL	**$51,378,765**	**$56,515,453**	**$58,917,416**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$27,566	$30,629	$33,692
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$8,048	$8,472	$8,896
FIRST YEAR O&M	**$81,927**	**$87,851**	**$93,775**

(rev. 11/08/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu   Location: Lualualei   Project Code: 628, 629, 630

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,032	21,771	19,600
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**24,786**	**21,553**	**19,398**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$7,445,625	$7,837,500	$8,229,375
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$710,031	$710,031	$710,031
SUB-TOTAL	**$53,860,640**	**$59,127,953**	**$61,660,541**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$41,349	$45,944	$50,538
Fixed O&M	$57,891	$60,938	$63,984
Land Lease	$8,048	$8,472	$8,896
FIRST YEAR O&M	**$107,288**	**$115,353**	**$123,418**

(rev. 11/08/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu | Location: Lualualei | Project Code: 88, 89, 90

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,160	20,143	17,127
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,933**	**19,942**	**16,951**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,658	$499,658	$499,658
SUB-TOTAL	**$36,067,805**	**$39,391,356**	**$41,095,538**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$25,817	$28,685	$31,554
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$6,374	$6,709	$7,044
FIRST YEAR O&M	**$76,077**	**$81,591**	**$87,105**

(rev. 11/08/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island Oahu Location: Lualualei Project Code: 631, 632, 633

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	1,965	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,940	22,561	19,182
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**25,685**	**22,335**	**18,985**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,658	$499,658	$499,658
SUB-TOTAL	**$37,854,755**	**$41,272,356**	**$43,070,588**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$38,725	$43,028	$47,330
Fixed O&M	$54,859	$57,746	$60,634
Land Lease	$6,374	$6,709	$7,044
FIRST YEAR O&M	**$99,957**	**$107,483**	**$115,008**

(rev. 11/08/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: North Ewa Plain   Project Code: 109, 110, 111

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	111,749	97,192	87,499
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**110,654**	**96,220**	**86,598**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$22,206,250	$23,375,000	$24,543,750
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$804,021	$1,005,026	$1,256,283
General Facilities			
Roads and Grading	$2,944,148	$3,271,275	$3,598,403
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$14,961,240	$14,961,240	$14,961,240
Project Contingency	$17,474,884	$17,474,884	$17,474,884
Initial Costs	$3,785,624	$3,785,624	$3,785,624
SUB-TOTAL	**$207,025,516**	**$226,847,379**	**$236,031,993**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$134,107	$149,008	$163,909
Fixed O&M	$123,500	$130,000	$136,500
Land Lease	$251,526	$264,764	$278,002
FIRST YEAR O&M	**$509,133**	**$543,772**	**$578,411**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu   Location: North Ewa Plain   Project Code: 652, 653, 654

Capacity (MW)	50		Stage (current/future)	current
Resource (kWh/m²)	1,909		Extent (PV module area, m²)	484,000
Project Life (years)	30		Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	125,158	108,855	97,999
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**123,931**	**107,766**	**96,990**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$33,309,375	$35,062,500	$36,815,625
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$804,021	$1,005,026	$1,256,283
General Facilities			
Roads and Grading	$2,944,148	$3,271,275	$3,598,403
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$14,961,240	$14,961,240	$14,961,240
Project Contingency	$17,474,884	$17,474,884	$17,474,884
Initial Costs	$3,785,624	$3,785,624	$3,785,624
SUB-TOTAL	**$218,128,641**	**$238,534,879**	**$248,303,868**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$201,161	$223,512	$245,863
Fixed O&M	$154,375	$162,500	$170,625
Land Lease	$251,526	$264,764	$278,002
FIRST YEAR O&M	**$607,062**	**$650,776**	**$694,490**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu | Location: North Ewa Plain | Project Code: 112, 113, 114

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	115,802	100,717	85,636
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**114,667**	**99,710**	**84,754**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$15,988,500	$16,830,000	$17,671,500
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$691,227	$864,033	$1,080,042
General Facilities			
Roads and Grading	$2,355,318	$2,617,020	$2,878,722
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$9,916,283	$9,916,283	$9,916,283
Project Contingency	$12,177,875	$12,177,875	$12,177,875
Initial Costs	$2,648,915	$2,648,915	$2,648,915
SUB-TOTAL	**$145,344,689**	**$158,095,913**	**$164,505,964**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$125,596	$139,551	$153,506
Fixed O&M	$117,031	$123,191	$129,351
Land Lease	$199,172	$209,655	$220,138
FIRST YEAR O&M	**$441,800**	**$472,397**	**$502,994**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: North Ewa Plain Project Code: 655, 656, 657

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	129,698	112,803	95,912
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**128,426**	**111,675**	**94,924**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$23,982,750	$25,245,000	$26,507,250
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$691,227	$864,033	$1,080,042
General Facilities			
Roads and Grading	$2,355,318	$2,617,020	$2,878,722
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$9,916,283	$9,916,283	$9,916,283
Project Contingency	$12,177,875	$12,177,875	$12,177,875
Initial Costs	$2,648,915	$2,648,915	$2,648,915
SUB-TOTAL	**$153,338,939**	**$166,510,913**	**$173,341,714**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$188,394	$209,327	$230,259
Fixed O&M	$146,290	$153,989	$161,689
Land Lease	$199,172	$209,655	$220,138
FIRST YEAR O&M	**$533,856**	**$572,971**	**$612,085**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: North Ewa Plain   Project Code: 103, 104, 105

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,350	19,438	17,500
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,131**	**19,244**	**17,320**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$713,492	$713,492	$713,492
SUB-TOTAL	**$51,382,226**	**$56,518,914**	**$58,920,877**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$26,822	$29,802	$32,782
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$48,293	$50,835	$53,377
FIRST YEAR O&M	**$121,428**	**$129,387**	**$137,346**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: North Ewa Plain Project Code: 646, 647, 648

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,032	21,771	19,600
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**24,786**	**21,553**	**19,398**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$7,445,625	$7,837,500	$8,229,375
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$713,492	$713,492	$713,492
SUB-TOTAL	**$53,864,101**	**$59,131,414**	**$61,664,002**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$40,233	$44,703	$49,173
Fixed O&M	$57,891	$60,938	$63,984
Land Lease	$48,293	$50,835	$53,377
FIRST YEAR O&M	**$146,417**	**$156,476**	**$166,534**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu — Location: North Ewa Plain — Project Code: 106, 107, 108

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,160	20,143	17,127
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,933**	**19,942**	**16,951**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,593	$499,593	$499,593
SUB-TOTAL	**$36,067,740**	**$39,391,291**	**$41,095,473**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$25,119	$27,910	$30,701
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$38,241	$40,254	$42,267
FIRST YEAR O&M	**$107,247**	**$114,361**	**$121,475**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu — Location: North Ewa Plain — Project Code: 649, 650, 651

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	1,909	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,940	22,561	19,182
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**25,685**	**22,335**	**18,985**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$499,593	$499,593	$499,593
SUB-TOTAL	**$37,854,690**	**$41,272,291**	**$43,070,523**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$37,679	$41,865	$46,052
Fixed O&M	$54,859	$57,746	$60,633
Land Lease	$38,241	$40,254	$42,267
FIRST YEAR O&M	**$130,778**	**$139,865**	**$148,951**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Pearl Harbor   Project Code: 79, 80, 81

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	111,749	97,192	87,499
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**110,654**	**96,220**	**86,598**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$22,206,250	$23,375,000	$24,543,750
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$804,021	$1,005,026	$1,256,283
General Facilities			
Roads and Grading	$2,944,148	$3,271,275	$3,598,403
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$14,961,240	$14,961,240	$14,961,240
Project Contingency	$17,474,884	$17,474,884	$17,474,884
Initial Costs	$3,779,314	$3,779,314	$3,779,314
SUB-TOTAL	**$207,019,206**	**$226,841,069**	**$236,025,683**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$145,388	$161,542	$177,696
Fixed O&M	$123,500	$130,000	$136,500
Land Lease	$167,685	$176,510	$185,336
FIRST YEAR O&M	**$436,572**	**$468,052**	**$499,532**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu   Location: Pearl Harbor   Project Code: 622, 623, 624

Capacity (MW)	50	Stage (current/future)	current
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	484,000
Project Life (years)	30	Construction Time (years)	4

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	125,158	108,855	97,999
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**123,931**	**107,766**	**96,990**
CAPITAL COSTS			
Process Capital			
PV Modules	$113,400,000	$126,000,000	$132,300,000
Array Structure & Foundations	$33,309,375	$35,062,500	$36,815,625
Power Condtioning Units	$9,506,250	$14,625,000	$15,356,250
Electrical & SCADA	$18,022,435	$18,204,480	$18,386,525
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,501,950	$1,581,000	$1,660,050
Legal Fees & Permitting	$804,021	$1,005,026	$1,256,283
General Facilities			
Roads and Grading	$2,944,148	$3,271,275	$3,598,403
Buildings and Fencing	$304,972	$338,858	$372,744
Engineering & Overhead	$14,961,240	$14,961,240	$14,961,240
Project Contingency	$17,474,884	$17,474,884	$17,474,884
Initial Costs	$3,779,314	$3,779,314	$3,779,314
SUB-TOTAL	**$218,122,331**	**$238,528,569**	**$248,297,558**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$218,082	$242,313	$266,544
Fixed O&M	$154,375	$162,500	$170,625
Land Lease	$167,685	$176,510	$185,336
FIRST YEAR O&M	**$540,141**	**$581,323**	**$622,505**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Pearl Harbor   Project Code: 82, 83, 84

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	115,802	100,717	85,636
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**114,667**	**99,710**	**84,754**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$15,988,500	$16,830,000	$17,671,500
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$691,227	$864,033	$1,080,042
General Facilities			
Roads and Grading	$2,355,318	$2,617,020	$2,878,722
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$9,916,283	$9,916,283	$9,916,283
Project Contingency	$12,177,875	$12,177,875	$12,177,875
Initial Costs	$2,644,069	$2,644,069	$2,644,069
SUB-TOTAL	**$145,339,843**	**$158,091,067**	**$164,501,118**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$136,161	$151,290	$166,419
Fixed O&M	$117,031	$123,191	$129,351
Land Lease	$132,782	$139,770	$146,759
FIRST YEAR O&M	**$385,974**	**$414,251**	**$442,528**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: Pearl Harbor Project Code: 625, 626, 627

Capacity (MW)	50	Stage (current/future)	future
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	383,200
Project Life (years)	30	Construction Time (years)	3

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	129,698	112,803	95,912
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**128,426**	**111,675**	**94,924**
CAPITAL COSTS			
Process Capital			
PV Modules	$79,380,000	$88,200,000	$92,610,000
Array Structure & Foundations	$23,982,750	$25,245,000	$26,507,250
Power Condtioning Units	$4,277,813	$6,581,250	$6,910,313
Electrical & SCADA	$14,210,690	$14,354,232	$14,497,775
Substation	$2,113,742	$2,224,992	$2,336,242
Overseas Shipping	$1,351,755	$1,422,900	$1,494,045
Legal Fees & Permitting	$691,227	$864,033	$1,080,042
General Facilities			
Roads and Grading	$2,355,318	$2,617,020	$2,878,722
Buildings and Fencing	$232,571	$258,412	$284,253
Engineering & Overhead	$9,916,283	$9,916,283	$9,916,283
Project Contingency	$12,177,875	$12,177,875	$12,177,875
Initial Costs	$2,644,069	$2,644,069	$2,644,069
SUB-TOTAL	**$153,334,093**	**$166,506,067**	**$173,336,868**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$204,242	$226,935	$249,629
Fixed O&M	$146,290	$153,989	$161,689
Land Lease	$132,782	$139,770	$146,759
FIRST YEAR O&M	**$483,313**	**$520,694**	**$558,076**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Pearl Harbor   Project Code: 73, 74, 75

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,350	19,438	17,500
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,131**	**19,244**	**17,320**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$712,289	$712,289	$712,289
SUB-TOTAL	**$51,381,023**	**$56,517,711**	**$58,919,674**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$29,077	$32,308	$35,539
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$32,196	$33,890	$35,585
FIRST YEAR O&M	**$107,585**	**$114,948**	**$122,311**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: Pearl Harbor Project Code: 616, 617, 618

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,032	21,771	19,600
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**24,786**	**21,553**	**19,398**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$7,445,625	$7,837,500	$8,229,375
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$712,289	$712,289	$712,289
SUB-TOTAL	**$53,862,898**	**$59,130,211**	**$61,662,799**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$43,616	$48,462	$53,308
Fixed O&M	$57,891	$60,938	$63,984
Land Lease	$32,196	$33,890	$35,585
FIRST YEAR O&M	**$133,702**	**$143,290**	**$152,877**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Oahu   Location: Pearl Harbor   Project Code: 76, 77, 78

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,160	20,143	17,127
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,933**	**19,942**	**16,951**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$498,671	$498,671	$498,671
SUB-TOTAL	**$36,066,818**	**$39,390,369**	**$41,094,551**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$27,232	$30,258	$33,284
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$25,494	$26,836	$28,178
FIRST YEAR O&M	**$96,614**	**$103,291**	**$109,968**

(rev. 11/07/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Oahu Location: Pearl Harbor Project Code: 619, 620, 621

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,940	22,561	19,182
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**25,685**	**22,335**	**18,985**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$498,671	$498,671	$498,671
SUB-TOTAL	**$37,853,768**	**$41,271,369**	**$43,069,601**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$40,848	$45,387	$49,926
Fixed O&M	$54,859	$57,746	$60,634
Land Lease	$25,494	$26,836	$28,178
FIRST YEAR O&M	**$121,201**	**$129,969**	**$138,737**

(rev. 11/07/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Oahu

Location: Lualualei
Ownrshp: DHHL

Project Code: 382, 383, 384

Capacity (MW)	80	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		156,870	149,400	134,460
Expected Losses (%)		10.5%	11.0%	12.1%
Net Energy (MWh/yr)		139,614	132,966	119,669
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		544	573	602
Solar Field		1632	1813	1994
HTF System		312	329	362
BOP		516	573	630
Interconnect		24	25	26
Overseas Shipping		371	390	410
Legal Fees & Permitting		5	5	6
General Facilities				
Roads & Grading		44	49	54
Buildings; fence		37	38	40
Water supply		19	22	24
Engineering & Overhead		250	263	276
Project Contingency		312	329	345
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,087	4,432	4,793
	$K	326,977	354,552	383,444

TRANSMISSION

Size (kV) -- Distance (Miles) --

		OPTIMISTIC	NOMINAL	CONSERVATIVE
Cost of Upgrade, $M		2	2	2
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	49.82	55.36	60.89
Variable O&M	cents/kWh	1.75	1.94	2.14
Land Lease	$K	124	138	152
FIRST YEAR O&M	$K	6,549	7,148	7,579

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Oahu

Location: Lualualei

Ownrshp: DHHL

Project Code: 385, 386, 387

Capacity (MW)	80
Resource (avg NIP,kWh/m2-day)	5.01
Project Life (years)	30
Geology Type	soil

Stage (current/future)	Future
Extent (# of units)	1
Construction Time (years)	1.5

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		180,401	171,810	154,629
Expected Losses (%)		9.4%	9.9%	10.9%
Net Energy (MWh/yr)		160,556	152,911	137,620
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		435	458	481
Solar Field		1142	1269	1396
HTF System		234	247	271
BOP		464	516	567
Interconnect		21	23	24
Overseas Shipping		371	390	410
Legal Fees & Permitting		4	4	5
General Facilities				
Roads & Grading		40	44	49
Buildings; fence		33	35	36
Water supply		19	22	24
Engineering & Overhead		212	224	235
Project Contingency		234	247	259
Initial Costs		15	16	17
TOTAL CAPITAL COSTS	$/kWe,ne	3,226	3,494	3,773
	$K	258,102	279,496	301,877

TRANSMISSION				
Size (kV)	--			
Distance (Miles)		--		
Cost of Upgrade, $M		2	2	2
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	29.89	33.21	36.54
Variable O&M	cents/kWh	1.40	1.55	1.71
Land Lease	$K	124	138	152
FIRST YEAR O&M	$K	4,760	5,170	5,426

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Oahu	Location:	Lualualei	Project Code:	328, 329, 330
		Ownrshp:	DHHL		

Capacity (MW)	50	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		83,812	79,821	71,839
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		18.8%	17.9%	16.1%
Net Energy (MWh/yr)		80,912	77,059	69,353
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.2	0.2	0.2
General Facilities				
Grubbing & Grading		89	99	114
Roads, buildings, fence		29	33	36
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		10	11	11
TOTAL CAPITAL COSTS	$/kWe,net	2,979	3,192	3,409
	$K	146,578	157,024	167,714

TRANSMISSION

Size (kV)	–	Distance (Miles)	–	
Cost of Upgrade, $M		2	2	2

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	67	75	82
FIRST YEAR O&M	$K	1,954	2,132	2,261
Total O&M, cents/kWh		2.38	2.64	2.91

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: 'Oahu	Location: Lualualei	Project Code:	331, 332, 333
	Ownrshp: DHHL		
Capacity (MW)	50	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.01	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		88,002	83,812	75,430
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		19.7%	18.8%	16.9%
Net Energy (MWh/yr)		84,957	80,912	72,820
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		279	310	341
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.2	0.2	0.2
General Facilities				
Grubbing & Grading		80	89	102
Roads, buildings, fence		29	33	36
Engineering & Overhead		86	90	95
Project Contingency		189	199	209
Initial Costs		7	8	8
TOTAL CAPITAL COSTS	$/kWe,net	1,773	1,954	2,139
	$K	87,247	96,131	105,234

TRANSMISSION				
Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		2	2	2
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	67	75	82
FIRST YEAR O&M	$K	1,373	1,494	1,572
Total O&M, cents/kWh		1.56	1.74	1.91

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island:	Oahu	Location:	N. Ewa Plain	Project Code:	388, 389, 390
		Ownrshp:	Private		

Capacity (MW)	80	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		152,173	144,927	130,434
Expected Losses (%)		10.5%	11.0%	12.1%
Net Energy (MWh/yr)		135,434	128,985	116,086
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		544	573	602
Solar Field		1632	1813	1994
HTF System		312	329	362
BOP		516	573	630
Interconnect		24	25	26
Overseas Shipping		371	390	410
Legal Fees & Permitting		5	5	6
General Facilities				
Roads & Grading		44	49	54
Buildings; fence		37	38	40
Water supply		19	22	24
Engineering & Overhead		250	263	276
Project Contingency		312	329	345
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,087	4,432	4,793
	$K	326,977	354,552	383,444

TRANSMISSION				
Size (kV)	--	Distance (Miles)	--	
Cost of Upgrade, $M		1	1	1

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	49.82	55.36	60.89
Variable O&M	cents/kWh	1.75	1.94	2.14
Land Lease	$K	1024	1137	1251
FIRST YEAR O&M	$K	7,376	8,070	8,601

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Oahu | Location: N. Ewa Plain | Project Code: 391, 392, 393
Ownrshp: Private

Capacity (MW)	80	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		174,999	166,666	149,999
Expected Losses (%)		9.4%	9.9%	10.9%
Net Energy (MWh/yr)		155,749	148,333	133,499
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		435	458	481
Solar Field		1142	1269	1396
HTF System		234	247	271
BOP		464	516	567
Interconnect		21	23	24
Overseas Shipping		371	390	410
Legal Fees & Permitting		4	4	5
General Facilities				
Roads & Grading		40	44	49
Buildings; fence		33	35	36
Water supply		19	22	24
Engineering & Overhead		212	224	235
Project Contingency		234	247	259
Initial Costs		15	16	17
TOTAL CAPITAL COSTS	$/kWe,ne	3,226	3,494	3,773
	$K	258,102	279,496	301,877

TRANSMISSION

Size (kV) -- | Distance (Miles) --

Cost of Upgrade, $M		1	1	1
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	29.89	33.21	36.54
Variable O&M	cents/kWh	1.40	1.55	1.71
Land Lease	$K	1024	1137	1251
FIRST YEAR O&M	$K	5,592	6,098	6,454

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Oahu
Location: N. Ewa Point
Ownrshp: Private
Project Code: 334, 335, 336

Capacity (MW)	50	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		81,302	77,431	69,688
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		18.2%	17.3%	15.6%
Net Energy (MWh/yr)		78,489	74,752	67,276
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.2	0.2	0.2
General Facilities				
Grubbing & Grading		89	99	114
Roads, buildings, fence		29	33	36
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		13	13	14
TOTAL CAPITAL COSTS	$/kWe,net	2,982	3,194	3,412
	$K	146,701	157,154	167,850

TRANSMISSION

Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		1	1	1
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	555	617	678
FIRST YEAR O&M	$K	2,420	2,651	2,834
Total O&M, cents/kWh		2.42	2.69	2.96

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island:	Oahu	Location:	N. Ewa Point	Project Code:	337, 338, 339
		Ownrshp:	Private		

Capacity (MW)	50	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	4.86	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		85,367	81,302	73,172
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		19.1%	18.2%	16.4%
Net Energy (MWh/yr)		82,414	78,489	70,640
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		279	310	341
Overseas Shipping		30	33	36
Legal Fees & Permitting		0.2	0.2	0.2
General Facilities				
Grubbing & Grading		80	89	102
Roads, buildings, fence		29	33	36
Engineering & Overhead		86	90	95
Project Contingency		189	199	209
Initial Costs		10	10	11
TOTAL CAPITAL COSTS	$/kWe,net	1,776	1,957	2,142
	$K	87,371	96,262	105,371

TRANSMISSION					
Size (kV)	--	Distance (Miles)	--		
Cost of Upgrade, $M			1	1	1
ANNUAL EXPENSES	1995$				
Fixed O&M	$/kW-yr		13.93	15.47	17.02
Variable O&M	cents/kWh		0.72	0.80	0.88
Land Lease	$K		555	617	678
FIRST YEAR O&M	$K		1,843	2,016	2,149
Total O&M, cents/kWh			1.59	1.77	1.94

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Oahu | Location: Pearl Harbor BZ | Project Code: 376, 377, 378
Ownrshp: USN

Capacity (MW)	80	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.26	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		164,698	156,855	141,170
Expected Losses (%)		10.5%	11.0%	12.1%
Net Energy (MWh/yr)		146,581	139,601	125,641
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		544	573	602
Solar Field		1632	1813	1994
HTF System		312	329	362
BOP		516	573	630
Interconnect		24	25	26
Overseas Shipping		371	390	410
Legal Fees & Permitting		5	5	6
General Facilities				
Roads & Grading		44	49	54
Buildings; fence		37	38	40
Water supply		19	22	24
Engineering & Overhead		250	263	276
Project Contingency		312	329	345
Initial Costs		21	22	23
TOTAL CAPITAL COSTS	$/kWe,ne	4,087	4,432	4,793
	$K	326,977	354,552	383,444

TRANSMISSION

Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		1	1	1

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	49.82	55.36	60.89
Variable O&M	cents/kWh	1.75	1.94	2.14
Land Lease	$K	473	525	578
FIRST YEAR O&M	$K	7,020	7,664	8,132

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Solar Thermal

Island: Oahu
Location: Pearl Harbor BZ
Ownrshp: USN
Project Code: 379, 380, 381

Capacity (MW)	80	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.26	Extent (# of units)	1
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		189,403	180,383	162,345
Expected Losses (%)		9.4%	9.9%	10.9%
Net Energy (MWh/yr)		168,568	160,541	144,487
CAPITAL COSTS	1995$ -- $/kWnet			
Process Capital				
Power Block		435	458	481
Solar Field		1142	1269	1396
HTF System		234	247	271
BOP		464	516	567
Interconnect		21	23	24
Overseas Shipping		371	390	410
Legal Fees & Permitting		4	4	5
General Facilities				
Roads & Grading		40	44	49
Buildings; fence		33	35	36
Water supply		19	22	24
Engineering & Overhead		212	224	235
Project Contingency		234	247	259
Initial Costs		15	16	17
TOTAL CAPITAL COSTS	$/kWe,ne	3,226	3,494	3,773
	$K	258,102	279,496	301,877

TRANSMISSION

Size (kV)	--	Distance (Miles) --		
Cost of Upgrade, $M		1	1	1
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	49.82	33.21	60.89
Variable O&M	cents/kWh	1.75	1.55	2.14
Land Lease	$K	473	525	578
FIRST YEAR O&M	$K	7,404	5,676	8,535

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Oahu
Location: Pearl Harbor
Ownrshp: USN
Project Code: 324, 325, 326

Capacity (MW)	50	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.26	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		87,994	83,804	75,423
Expected Losses (%)		3.3%	3.5%	3.8%
Capacity Factor (net)		19.7%	18.8%	16.9%
Net Energy (MWh/yr)		84,949	80,904	72,814
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		910	958	1006
Aximuth/Elevation Drives		222	234	246
Facets		194	204	214
Dish Control System		8	8	8
Stirling Engine/Generator		831	924	1016
Installation		294	310	325
Overseas Shipping		39	41	44
Legal Fees & Permitting		0.2	0.2	0.2
General Facilities				
Grubbing & Grading		89	99	114
Roads, buildings, fence		29	33	36
Engineering & Overhead		101	106	111
Project Contingency		252	265	278
Initial Costs		11	12	13
TOTAL CAPITAL COSTS	$/kWe,net	2,980	3,193	3,410
	$K	146,637	157,087	167,779

TRANSMISSION

Size (kV)	--	Distance (Miles)	--		
Cost of Upgrade, $M			1	1	1

ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	23.21	25.79	28.37
Variable O&M	cents/kWh	0.90	1.00	1.10
Land Lease	$K	256	285	313
FIRST YEAR O&M	$K	2,179	2,381	2,530
Total O&M, cents/kWh		2.31	2.57	2.82

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Oahu | Location: Pearl Harbor | Project Code: 397, 398, 399
Ownrshp: USN

Capacity (MW)	50	Stage (current/future)	Future
Resource (avg NIP,kWh/m2-day)	5.26	Extent (# of units)	1200
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

		OPTIMISTIC		NOMINAL		CONSERVATIVE
ENERGY PRODUCTION						
Gross Energy (MWh/yr)		92,394		87,994		79,194
Expected Losses (%)		3.1%		3.3%		3.6%
Capacity Factor (net)		20.7%		19.7%		17.7%
Net Energy (MWh/yr)		89,197		84,949		76,454
CAPITAL COSTS	1995$					
Process Capital		$/kWe,net		$/kWe,net		$/kWe,net
Support Structure		391		435		478
Aximuth/Elevation Drives		115		128		140
Facets		151		168		184
Dish Control System		5		5		6
Stirling Engine/Generator		412		458		503
Installation		279		310		341
Overseas Shipping		30		33		36
Legal Fees & Permitting		0.2		0.2		0.2
General Facilities						
Grubbing & Grading		80		89		102
Roads, buildings, fence		29		33		36
Engineering & Overhead		86		90		95
Project Contingency		189		199		209
Initial Costs		8		9		9
TOTAL CAPITAL COSTS	$/kWe,net	1,774		1,955		2,140
	$K	87,304		96,192		105,298

TRANSMISSION
Size (kV) – Distance (Miles) –

		OPTIMISTIC	NOMINAL	CONSERVATIVE
Cost of Upgrade, $M		1	1	1
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	13.93	15.47	17.02
Variable O&M	cents/kWh	0.72	0.80	0.88
Land Lease	$K	256	285	313
FIRST YEAR O&M	$K	1,593	1,736	1,835
Total O&M, cents/kWh		1.52	1.69	1.86

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island: Oahu — Location: Kahuku Point — Project Code: 718, 719, 720

Project size (MWe)	60	Stage (current/future)	future
Resource (kW/m, avg.)	14.5	Extent (no. x dia. buoys)	360 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	732,231	732,231	732,231
Wave energy absorbtion efficiency	51%	42%	21%
Absorbed energy (MWh/yr)	374,941	304,951	152,475
Conversion & sea-to-shore transmission efficiency	74%	77%	81%
Landed energy at 100% availability (MWh/yr)	279,214	234,663	122,965
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	265,253	211,197	98,372
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	35,430,000	53,145,000	70,860,000
Pelton turbine/generator	17,625,000	17,625,000	17,625,000
Balance of mechanical & electrical plant	6,712,000	6,712,000	6,712,000
Mooring hardware	8,961,000	8,961,000	8,961,000
Deployment	4,909,000	7,364,000	9,818,000
Sea-to-shore transmission	4,891,000	4,891,000	4,891,000
Onshore substation	3,172,000	3,172,000	3,172,000
Legal fees and permitting	795,000	845,000	896,000
Process Capital Sub-Total	82,495,000	102,715,000	122,935,000
General Facilities	4,125,000	10,271,000	18,440,000
Engineering & Overhead	8,249,000	10,271,000	12,293,000
Project Contingency	9,487,000	12,326,000	15,367,000
Initial Costs	2,307,000	3,221,000	4,386,000
TOTAL PLANT COST	106,663,000	138,804,000	173,421,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	2,000,000	2,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	1,650,000	4,109,000	7,376,000
Amortized periodic replacements	994,000	2,000,000	4,685,000
FIRST YEAR O&M COST	2,644,000	6,108,000	12,061,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Oahu	Location	Kahuku Point	Project Code	715, 716, 717

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	14.5	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	366,116	366,116	366,116
Wave energy absorbtion efficiency	51%	42%	21%
Absorbed energy (MWh/yr)	187,471	152,475	76,238
Conversion & sea-to-shore transmission efficiency	74%	77%	81%
Landed energy at 100% availability (MWh/yr)	139,621	117,342	61,486
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	132,640	105,608	49,188
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,137,000	3,137,000	3,137,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	749,000
Process Capital Sub-Total	43,149,000	53,715,000	64,282,000
General Facilities	2,157,000	5,372,000	9,642,000
Engineering & Overhead	4,315,000	5,372,000	6,428,000
Project Contingency	4,962,000	6,446,000	8,035,000
Initial Costs	1,205,000	1,682,000	2,287,000
TOTAL PLANT COST	55,789,000	72,586,000	90,675,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	863,000	2,149,000	3,857,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,366,000	3,162,000	6,236,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Oahu   Location Makapuu Point   Project Code 258,259,260

Project size (MWe)	60	Stage (current/future)	future
Resource (kW/m, avg.)	15.0	Extent (no. x dia. buoys)	360 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	757,471	757,471	757,471
Wave energy absorbtion efficiency	53%	43%	22%
Absorbed energy (MWh/yr)	400,533	327,589	163,794
Conversion & sea-to-shore transmission efficiency	73%	76%	80%
Landed energy at 100% availability (MWh/yr)	294,082	249,309	131,645
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	279,377	224,378	105,316
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	35,430,000	53,145,000	70,860,000
Pelton turbine/generator	17,625,000	17,625,000	17,625,000
Balance of mechanical & electrical plant	6,712,000	6,712,000	6,712,000
Mooring hardware	8,961,000	8,961,000	8,961,000
Deployment	4,909,000	7,364,000	9,818,000
Sea-to-shore transmission	5,405,000	5,405,000	5,405,000
Onshore substation	3,172,000	3,172,000	3,172,000
Legal fees and permitting	796,000	846,000	897,000
Process Capital Sub-Total	83,010,000	103,230,000	123,450,000
General Facilities	4,151,000	10,323,000	18,517,000
Engineering & Overhead	8,301,000	10,323,000	12,345,000
Project Contingency	9,546,000	12,388,000	15,431,000
Initial Costs	2,321,000	3,236,000	4,403,000
TOTAL PLANT COST	107,329,000	139,500,000	174,146,000
ONSHORE TRANSMISSION UPGRADE	1,000,000	1,000,000	1,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	1,660,000	4,129,000	7,407,000
Amortized periodic replacements	994,000	2,000,000	4,685,000
FIRST YEAR O&M COST	2,654,000	6,129,000	12,092,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island: Oahu   Location: Makapuu Point   Project Code: 252,253,254

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	15.0	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	378,736	378,736	378,736
Wave energy absorbtion efficiency	53%	43%	22%
Absorbed energy (MWh/yr)	200,267	163,794	81,897
Conversion & sea-to-shore transmission efficiency	73%	76%	80%
Landed energy at 100% availability (MWh/yr)	147,068	124,675	65,829
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	139,714	112,208	52,663
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,549,000	3,549,000	3,549,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	698,000	724,000	750,000
Process Capital Sub-Total	43,561,000	54,128,000	64,694,000
General Facilities	2,178,000	5,413,000	9,704,000
Engineering & Overhead	4,356,000	5,413,000	6,469,000
Project Contingency	5,010,000	6,495,000	8,087,000
Initial Costs	1,217,000	1,694,000	2,301,000
TOTAL PLANT COST	56,322,000	73,142,000	91,255,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	871,000	2,165,000	3,882,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,374,000	3,179,000	6,261,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Oahu	Location	Mokapu Point	Project Code	261,262,263

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	12.5	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	314,861	314,861	314,861
Wave energy absorbtion efficiency	55%	45%	22%
Absorbed energy (MWh/yr)	171,837	140,429	70,214
Conversion & sea-to-shore transmission efficiency	75%	78%	80%
Landed energy at 100% availability (MWh/yr)	129,382	108,851	56,358
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	122,913	97,966	45,087
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,878,000	3,878,000	3,878,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	698,000	725,000	751,000
Process Capital Sub-Total	43,891,000	54,458,000	65,024,000
General Facilities	2,195,000	5,446,000	9,754,000
Engineering & Overhead	4,389,000	5,446,000	6,502,000
Project Contingency	5,047,000	6,535,000	8,128,000
Initial Costs	1,225,000	1,704,000	2,312,000
TOTAL PLANT COST	56,748,000	73,588,000	91,719,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	878,000	2,178,000	3,901,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,380,000	3,192,000	6,280,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Oahu Location Northeast Coast 2A Project Code 121,122,123

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	13.9	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	349,652	349,652	349,652
Wave energy absorbtion efficiency	52%	43%	21%
Absorbed energy (MWh/yr)	183,073	149,100	74,550
Conversion & sea-to-shore transmission efficiency	75%	77%	81%
Landed energy at 100% availability (MWh/yr)	136,775	115,226	60,093
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	129,936	103,704	48,075
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,220,000	3,220,000	3,220,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	750,000
Process Capital Sub-Total	43,231,000	53,798,000	64,364,000
General Facilities	2,162,000	5,380,000	9,655,000
Engineering & Overhead	4,323,000	5,380,000	6,436,000
Project Contingency	4,972,000	6,456,000	8,046,000
Initial Costs	1,208,000	1,684,000	2,290,000
TOTAL PLANT COST	55,896,000	72,697,000	90,791,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	865,000	2,152,000	3,862,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,367,000	3,166,000	6,241,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Oahu	Location	Northeast Coast 2C	Project Code	255,256,257

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	11.9	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	301,173	301,173	301,173
Wave energy absorbtion efficiency	58%	47%	24%
Absorbed energy (MWh/yr)	173,434	142,518	71,259
Conversion & sea-to-shore transmission efficiency	77%	79%	81%
Landed energy at 100% availability (MWh/yr)	132,922	113,145	57,498
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	126,276	101,831	45,998
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,137,000	3,137,000	3,137,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	749,000
Process Capital Sub-Total	43,149,000	53,715,000	64,282,000
General Facilities	2,157,000	5,372,000	9,642,000
Engineering & Overhead	4,315,000	5,372,000	6,428,000
Project Contingency	4,962,000	6,446,000	8,035,000
Initial Costs	1,205,000	1,682,000	2,287,000
TOTAL PLANT COST	55,789,000	72,586,000	90,675,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	863,000	2,149,000	3,857,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,366,000	3,162,000	6,236,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island Oahu   Location Waimanalo Bay   Project Code 664, 665, 666

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	9.3	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	233,480	233,480	233,480
Wave energy absorbtion efficiency	64%	53%	27%
Absorbed energy (MWh/yr)	149,164	123,782	61,891
Conversion & sea-to-shore transmission efficiency	79%	80%	81%
Landed energy at 100% availability (MWh/yr)	117,555	98,841	49,924
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	111,677	88,957	39,939
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,302,000	3,302,000	3,302,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	750,000
Process Capital Sub-Total	43,314,000	53,880,000	64,447,000
General Facilities	2,166,000	5,388,000	9,667,000
Engineering & Overhead	4,331,000	5,388,000	6,445,000
Project Contingency	4,981,000	6,466,000	8,056,000
Initial Costs	1,210,000	1,687,000	2,293,000
TOTAL PLANT COST	56,002,000	72,809,000	90,907,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	866,000	2,155,000	3,867,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,369,000	3,169,000	6,246,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kahuku Project Code: 538, 539, 540 (leave blank)

Capacity (MW)	80	Stage (current/future)	Current
Resource (mph, avg.)	16.4	Extent (# of units)	320
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	185,690	168,809	151,928
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	142,900	121,469	101,726
CAPITAL COSTS			
Process Capital			
Turbines & Towers	43,874,914	48,749,904	53,624,894
Foundations	3,492,720	3,528,000	3,563,280
Assembly & Checkout	2,067,358	2,088,240	2,109,122
Electrical Infrastructure	7,784,357	7,862,987	7,941,617
Sub-Station	4,405,484	4,449,984	4,494,484
Overseas Shipping	1,546,776	1,562,400	1,578,024
Legal Fees & Permitting	372,468	465,585	581,982
General Facilities			
Roads & Grading	680,665	687,540	694,415
Control System	704,532	711,648	718,764
Control Buildings	295,917	298,906	301,895
Central Building	85,121	94,579	118,223
Engineering & Overhead	6,531,031	7,049,977	7,572,670
Project Contingency	7,184,134	7,754,975	8,329,937
Initial Costs	2,825,466	2,964,615	3,138,993
SUB-TOTAL	$81,850,942	$88,269,340	$94,768,302
TRANSMISSION			
Cost of Upgrade	$15,000,000	$15,000,000	$15,000,000
ANNUAL EXPENSES			
Variable O&M	825,250	637,712	587,466
Fixed O&M	1,099,791	1,110,900	1,122,009
Land Lease	677,981	713,664	749,347
FIRST YEAR O&M	$2,603,021	$2,462,276	$2,458,822

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kahuku Project Code: 541,542,543
(leave blank)

Capacity (MW)	80	Stage (current/future)	Future
Resource (mph, avg.)	16.4	Extent (# of units)	266
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	231,686	210,624	189,561
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	178,298	151,558	126,924
CAPITAL COSTS			
Process Capital			
Turbines & Towers	38,695,754	42,995,283	49,444,575
Foundations	2,845,257	2,873,997	2,902,737
Assembly & Checkout	1,701,306	1,718,491	1,735,676
Electrical Infrastructure	7,647,638	7,724,887	7,802,135
Sub-Station	4,405,484	4,449,984	4,494,484
Overseas Shipping	1,285,758	1,298,745	1,311,732
Legal Fees & Permitting	357,519	446,899	558,623
General Facilities			
Roads & Grading	566,153	571,872	577,591
Control System	579,785	585,642	591,498
Control Buildings	243,521	245,981	248,440
Central Building	85,121	94,579	118,223
Engineering & Overhead	5,841,330	6,300,636	6,978,572
Project Contingency	6,425,463	6,930,699	7,676,429
Initial Costs	2,662,333	2,771,091	2,996,224
SUB-TOTAL	$73,342,422	$79,008,784	$87,436,940
TRANSMISSION			
Cost of Upgrade	$15,000,000	$15,000,000	$15,000,000
ANNUAL EXPENSES			
Variable O&M	1,009,076	779,764	718,325
Fixed O&M	1,077,795	1,088,682	1,099,569
Land Lease	700,484	737,352	774,220
FIRST YEAR O&M	$2,787,355	$2,605,798	$2,592,114

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu   Location Kahuku   Project Code: 532, 533, 534
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Capacity (MW)	50	Stage (current/future)	Current
Resource (mph, avg.)	16.4	Extent (# of units)	200
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	116,056	105,505	94,955
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	89,313	75,918	63,579
CAPITAL COSTS			
Process Capital			
Turbines & Towers	27,421,821	30,468,690	33,515,559
Foundations	2,182,950	2,205,000	2,227,050
Assembly & Checkout	1,292,099	1,305,150	1,318,202
Electrical Infrastructure	4,865,223	4,914,367	4,963,510
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	966,735	976,500	986,265
Legal Fees & Permitting	320,015	400,019	500,024
General Facilities			
Roads & Grading	426,195	430,500	434,805
Control System	440,332	444,780	449,228
Control Buildings	184,948	186,816	188,684
Central Building	85,121	94,579	118,223
Engineering & Overhead	4,093,887	4,420,764	4,751,060
Project Contingency	4,503,275	4,862,840	5,226,166
Initial Costs	1,827,113	1,914,695	2,024,556
SUB-TOTAL	$51,363,142	$55,405,940	$59,512,385
TRANSMISSION			
Cost of Upgrade	$2,000,000	$2,000,000	$2,000,000
ANNUAL EXPENSES			
Variable O&M	515,781	398,570	367,166
Fixed O&M	687,369	694,313	701,256
Land Lease	423,738	446,040	468,342
FIRST YEAR O&M	$1,626,888	$1,538,923	$1,536,764

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kahuku Project Code: 535,536,537 (leave blank)

Capacity (MW)	50	Stage (current/future)	Future
Resource (mph, avg.)	16.4	Extent (# of units)	166
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	144,586	131,442	118,298
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	111,268	94,581	79,208
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,148,478	26,831,642	30,856,389
Foundations	1,775,612	1,793,547	1,811,482
Assembly & Checkout	1,061,717	1,072,442	1,083,166
Electrical Infrastructure	4,772,586	4,820,794	4,869,002
Sub-Station	2,753,428	2,781,240	2,809,052
Overseas Shipping	802,390	810,495	818,600
Legal Fees & Permitting	310,563	388,203	485,254
General Facilities			
Roads & Grading	354,095	357,672	361,249
Control System	361,821	365,476	369,130
Control Buildings	151,972	153,507	155,042
Central Building	85,121	94,579	118,223
Engineering & Overhead	3,657,778	3,946,960	4,373,659
Project Contingency	4,023,556	4,341,656	4,811,025
Initial Costs	1,726,725	1,795,215	1,936,592
SUB-TOTAL	$45,985,841	$49,553,427	$54,857,866
TRANSMISSION			
Cost of Upgrade	$2,000,000	$2,000,000	$2,000,000
ANNUAL EXPENSES			
Variable O&M	629,724	486,620	448,278
Fixed O&M	673,622	680,426	687,231
Land Lease	437,144	460,152	483,160
FIRST YEAR O&M	$1,740,490	$1,627,198	$1,618,668

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kahuku Project Code: 526,527,528
(leave blank)

Capacity (MW)	30	Stage (current/future)	Current
Resource (mph, avg.)	16.4	Extent (# of units)	120
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	69,634	63,303	56,973
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	53,588	45,551	38,147
CAPITAL COSTS			
Process Capital			
Turbines & Towers	16,788,870	18,654,300	20,519,730
Foundations	1,309,770	1,323,000	1,336,230
Assembly & Checkout	775,259	783,090	790,921
Electrical Infrastructure	2,919,134	2,948,620	2,978,106
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	580,041	585,900	591,759
Legal Fees & Permitting	285,793	357,241	446,551
General Facilities			
Roads & Grading	256,549	259,140	261,731
Control System	264,199	266,868	269,537
Control Buildings	110,969	112,090	113,210
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,502,776	2,705,357	2,911,143
Project Contingency	2,753,054	2,975,893	3,202,257
Initial Costs	1,173,046	1,227,530	1,295,661
SUB-TOTAL	$31,456,637	$33,962,352	$36,520,492
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	309,469	239,142	220,300
Fixed O&M	412,422	416,588	420,753
Land Lease	254,243	267,624	281,005
FIRST YEAR O&M	$976,133	$923,354	$922,058

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kahuku Project Code: 529, 530, 531
(leave blank)

Capacity (MW)	30	Stage (current/future)	Future
Resource (mph, avg.)	16.4	Extent (# of units)	100
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	87,100	79,182	71,264
Expected Losses (%)	23%	28%	33%
Net Energy (MWh/yr)	67,029	56,977	47,716
CAPITAL COSTS			
Process Capital			
Turbines & Towers	14,844,159	16,493,510	18,967,537
Foundations	1,069,646	1,080,450	1,091,255
Assembly & Checkout	639,589	646,049	652,510
Electrical Infrastructure	2,875,052	2,904,093	2,933,134
Sub-Station	1,652,057	1,668,744	1,685,431
Overseas Shipping	483,368	488,250	493,133
Legal Fees & Permitting	280,209	350,262	437,827
General Facilities			
Roads & Grading	214,137	216,300	218,463
Control System	217,964	220,166	222,368
Control Buildings	91,549	92,474	93,399
Central Building	85,121	94,579	118,223
Engineering & Overhead	2,245,285	2,425,488	2,691,328
Project Contingency	2,469,814	2,668,036	2,960,461
Initial Costs	1,118,452	1,161,488	1,249,273
SUB-TOTAL	$28,286,400	$30,509,889	$33,814,340
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	379,352	293,144	270,047
Fixed O&M	404,173	408,256	412,338
Land Lease	263,340	277,200	291,060
FIRST YEAR O&M	$1,046,865	$978,600	$973,445

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kaena Point Project Code: 520,521,522
(leave blank)

Capacity (MW)	15	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	60
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	36,002	32,729	29,456
Expected Losses (%)	18%	23%	28%
Net Energy (MWh/yr)	29,553	25,230	21,234
CAPITAL COSTS			
Process Capital			
Turbines & Towers	8,394,435	9,327,150	10,259,865
Foundations	586,278	592,200	598,122
Assembly & Checkout	387,630	391,545	395,460
Electrical Infrastructure	1,717,138	1,734,482	1,751,827
Sub-Station	826,028	834,372	842,716
Overseas Shipping	290,021	292,950	295,880
Legal Fees & Permitting	259,620	324,525	405,656
General Facilities			
Roads & Grading	151,767	153,300	154,833
Control System	132,100	133,434	134,768
Control Buildings	55,484	56,045	56,605
Central Building	85,121	94,579	118,223
Engineering & Overhead	1,288,562	1,393,458	1,501,396
Project Contingency	1,417,418	1,532,804	1,651,535
Initial Costs	656,042	682,279	716,348
SUB-TOTAL	$16,247,643	$17,543,124	$18,883,235
TRANSMISSION			
Cost of Upgrade	$1,500,000	$1,500,000	$1,500,000
ANNUAL EXPENSES			
Variable O&M	170,667	132,456	122,626
Fixed O&M	206,211	208,294	210,377
Land Lease	42,374	44,604	46,834
FIRST YEAR O&M	$419,252	$385,354	$379,837

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island: Oahu | Location: Kaena Point | Project Code: 523,524,525 (leave blank)

Capacity (MW)	15	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	50
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	45,033	40,939	36,845
Expected Losses (%)	18%	23%	28%
Net Energy (MWh/yr)	36,966	31,558	26,560
CAPITAL COSTS			
Process Capital			
Turbines & Towers	7,422,080	8,246,755	9,483,768
Foundations	478,794	483,630	488,466
Assembly & Checkout	319,794	323,025	326,255
Electrical Infrastructure	1,691,207	1,708,290	1,725,373
Sub-Station	826,028	834,372	842,716
Overseas Shipping	241,684	244,125	246,566
Legal Fees & Permitting	256,838	321,048	401,310
General Facilities			
Roads & Grading	126,819	128,100	129,381
Control System	108,982	110,083	111,184
Control Buildings	45,775	46,237	46,699
Central Building	85,121	94,579	118,223
Engineering & Overhead	1,160,312	1,254,024	1,391,994
Project Contingency	1,276,343	1,379,427	1,531,194
Initial Costs	633,747	654,050	697,884
SUB-TOTAL	$14,673,525	$15,827,745	$17,541,014
TRANSMISSION			
Cost of Upgrade	$1,500,000	$1,500,000	$1,500,000
ANNUAL EXPENSES			
Variable O&M	209,207	162,367	150,317
Fixed O&M	202,087	204,128	206,169
Land Lease	43,890	46,200	48,510
FIRST YEAR O&M	$455,184	$412,695	$404,996

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu Location Kaena Point Project Code: 514,515,516
(leave blank)

Capacity (MW)	2	Stage (current/future)	Current
Resource (mph, avg.)	15.7	Extent (# of units)	8
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	4,800	4,364	3,928
Expected Losses (%)	14%	19%	24%
Net Energy (MWh/yr)	4,151	3,555	3,003
CAPITAL COSTS			
Process Capital			
Turbines & Towers	1,175,221	1,305,801	1,436,381
Foundations	78,170	78,960	79,750
Assembly & Checkout	51,684	52,206	52,728
Electrical Infrastructure	228,952	231,264	233,577
Sub-Station	110,137	111,250	112,362
Overseas Shipping	38,669	39,060	39,451
Legal Fees & Permitting	236,157	295,197	368,996
General Facilities			
Roads & Grading	22,037	22,260	22,483
Control System	17,613	17,791	17,969
Control Buildings	7,398	7,473	7,547
Central Building	11,349	12,611	15,763
Engineering & Overhead	197,739	217,387	238,701
Project Contingency	217,513	239,126	262,571
Initial Costs	229,336	234,214	240,491
SUB-TOTAL	$2,621,977	$2,864,599	$3,128,769
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	23,970	18,664	17,344
Fixed O&M	27,495	27,773	28,050
Land Lease	5,650	5,947	6,245
FIRST YEAR O&M	$57,114	$52,384	$51,638

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Oahu   Location Kaena Point   Project Code: 517,518,519
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Capacity (MW)	2	Stage (current/future)	Future
Resource (mph, avg.)	15.7	Extent (# of units)	6
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	5,404	4,913	4,421
Expected Losses (%)	14%	19%	24%
Net Energy (MWh/yr)	4,673	4,002	3,381
CAPITAL COSTS			
Process Capital			
Turbines & Towers	935,182	1,039,091	1,194,955
Foundations	57,455	58,036	58,616
Assembly & Checkout	38,375	38,763	39,151
Electrical Infrastructure	202,945	204,995	207,045
Sub-Station	110,137	111,250	112,362
Overseas Shipping	29,002	29,295	29,588
Legal Fees & Permitting	235,460	294,325	367,906
General Facilities			
Roads & Grading	17,048	17,220	17,392
Control System	13,078	13,210	13,342
Control Buildings	5,493	5,548	5,604
Central Building	11,349	12,611	15,763
Engineering & Overhead	165,552	182,434	206,172
Project Contingency	182,108	200,678	226,790
Initial Costs	229,015	232,813	239,889
SUB-TOTAL	$2,232,200	$2,440,268	$2,734,575
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	26,444	20,591	19,134
Fixed O&M	26,945	27,217	27,489
Land Lease	5,267	5,544	5,821
FIRST YEAR O&M	$58,656	$53,352	$52,444

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Methanol

Island: Kauai　　Location: Lihue　　Project Code: 210,211,212

Capacity (MW):	47	Stage (current/future):	future
Resource (dry tons/year):	134,509	Extent (harvested acres/year):	2,205
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	319,738	290,671	261,604
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	319,738	290,671	261,604
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	7,229,993	9,037,491	10,844,989
Gasification	2,822,740	3,528,425	4,234,110
Gas conditioning	4,554,161	5,692,701	6,831,241
Compression	9,097,828	11,372,285	13,646,742
Acid gas removal/cooling	4,134,422	5,168,028	6,201,634
MeOH syn/purification	11,469,350	14,336,687	17,204,024
Utilities/auxiliary	9,832,370	12,290,463	14,748,555
Legal fees & permitting	594,852	743,565	892,278
General Facilities			
Road construction	1,436,006	1,795,007	2,154,009
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	4,973,572	6,216,964	7,460,357
Project contingency	5,770,922	7,213,652	8,656,383
Initial cost	2,399,133	2,998,917	3,598,700
SUB-TOTAL	65,879,276	82,349,093	98,818,912

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	6,812,836	8,516,045	10,219,254
Fixed O&M ($)	5,449,772	6,812,215	8,174,658
Land Lease	634,200	792,750	951,300
FIRST YEAR O&M	12,896,808	16,121,010	19,345,212

Note: 1 MW = 0.5274 MGPY MeOH
47 MW = 25 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Kauai | Location: Lihue | Project Code: 189,190,191

Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons/year):	125,003	Extent (harvested acres/year):	2,025
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	OPTIMISTIC	NOMINAL	CONSERVATIVE
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	6,142,154	7,226,064	8,309,973
Gasification & compressor/precooler	843,041	991,813	1,140,585
Physical cleanup	17,235,500	20,277,059	23,318,618
Ash handling	321,158	377,833	434,508
Gas turbine	334,540	393,576	452,613
Balance of plant	6,490,076	7,635,383	8,780,691
Legal fee & permitting	579,916	682,254	784,592
General Facilities			
Road construction	1,401,663	1,649,016	1,896,368
Plantation lab	119,517	140,608	161,699
Equip. repair shop	1,542,155	1,814,300	2,086,445
Engineering & overhead	3,194,639	3,758,398	4,322,158
Project contingency	3,820,436	4,494,630	5,168,825
Initial cost	1,564,974	1,841,146	2,117,318
SUB-TOTAL	43,589,769	51,282,080	58,974,393

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES	OPTIMISTIC	NOMINAL	CONSERVATIVE
Variable O&M ($)	4,902,441	5,767,577	6,632,714
Fixed O&M ($)	2,544,138	2,993,103	3,442,069
Land Lease	619,863	729,250	838,638
FIRST YEAR O&M	8,066,442	9,489,930	10,913,421

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Kauai | Location: Lihue | Project Code: 201, 202, 203

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	106,500	Extent (harvested acres/year):	6,231
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,360,521	4,200,651	5,040,781
Initial cost	1,986,536	2,483,170	2,979,804
SUB-TOTAL	38,952,263	48,690,329	58,428,393

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	9,120,399	11,400,499	13,680,599
Fixed O&M ($)	3,333,850	4,167,313	5,000,775
Land Lease	258,840	323,550	388,260
FIRST YEAR O&M	12,713,089	15,891,362	19,069,634

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Kauai | Location: Lihue | Project Code: 192, 193, 194

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	104,011	Extent (harvested acres/year):	1,647
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Road construction	1,072,751	1,340,939	1,609,127
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,624,188	4,530,235	5,436,282
Initial cost	1,426,034	1,782,543	2,139,051
SUB-TOTAL	41,292,106	51,615,133	61,938,158

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	4,113,589	5,141,986	6,170,384
Fixed O&M ($)	2,476,486	3,095,608	3,714,730
Land Lease	476,200	595,250	714,300
FIRST YEAR O&M	7,066,275	8,832,844	10,599,414

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops & Organic Wastes - Electricity

Island: Kauai	Location: Kaumakani	Project Code: 222,223,224	
Capacity (MW electricity):	50	Stage (current/future):	future
Resource (tree crops)(dry tons/year):	163,226	Extent (harvested acres/year):	3,070
organic wastes (wet tons/yr)	80,300		
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	337,260	306,600	275,940
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	337,260	306,600	275,940
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	7,600,190	9,500,238	11,400,286
Feed handling and prep.	8,370,725	10,463,407	12,556,088
Gasification & compressor/precooler	14,769,967	18,462,459	22,154,951
Physical cleanup	9,047,943	1,131,179	1,357,415
Ash handling	872,624	1,090,780	1,308,936
Gas turbine	19,617,878	24,522,347	29,426,816
Balance of plant	11,139,421	13,924,276	16,709,131
Legal fees & permitting	611,189	763,986	916,783
General Facilities			
Road construction	1,999,510	2,006,523	2,999,266
Plantation lab	112,487	2,499,388	168,730
Equip. repair shop	1,451,440	140,608	2,177,160
		1,814,300	
Engineering & overhead	6,388,694	7,985,867	9,583,041
Project contingency	7,307,905	9,134,881	10,961,857
Initial cost	2,705,201	3,381,502	4,057,802
SUB-TOTAL	91,995,174	106,821,741	125,778,262

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	6,159,274	8,381,643	10,604,012
Fixed O&M ($)	3,981,361	4,976,701	5,972,041
Land Lease	879,300	1,099,125	1,318,950
FIRST YEAR O&M	11,019,935	14,457,469	17,895,003

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Methanol

Island: Kauai	Location: Kaumakani	Project Code:	207, 208, 209
Capacity (MW electricity):	47	Stage (current/future):	future
Resource (dry tons/year):	134,509	Extent (harvested acres/year):	2,465
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	319,738	290,671	261,604
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	319,738	290,671	261,604
CAPITAL COSTS			
Process Capital			
Feed handling, preparation	7,229,993	9,037,491	10,844,989
Gasification	2,822,740	3,528,425	4,234,110
Gas conditioning	4,554,161	5,692,701	6,831,241
Compression	9,097,828	11,372,285	13,646,742
Acid gas removal/cooling	4,134,422	5,168,028	6,201,634
MeOH syn/purification	11,469,350	14,336,687	17,204,024
Utilities/auxiliary	9,832,370	12,290,463	14,748,555
Legal fees & permitting	594,852	743,565	892,278
General Facilities			
Road construction	1,605,218	2,006,523	2,407,827
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	4,973,572	6,216,964	7,460,357
Project contingency	5,787,843	7,234,804	8,681,765
Initial cost	2,466,888	3,083,610	3,700,332
SUB-TOTAL	66,133,164	82,666,454	99,199,744

TRANSMISSION			
Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	7,375,141	9,218,926	11,062,711
Fixed O&M ($)	5,483,614	6,854,518	8,225,421
Land Lease	707,800	884,750	1,061,700
FIRST YEAR O&M	13,566,555	16,958,194	20,349,832

Note: 1 MW = 0.5274 MGPY MeOH
47 MW - 25 MGPY MeOH

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Kauai | Location: Kaumakani | Project Code: 195,196,197

Capacity (MW electricity):	25	Stage (current/future):	current
Resource (dry tons/year):	125,003	Extent (harvested acres/year):	2,273
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	5,780,851	7,226,064	8,671,276
Gasification & compressor/precooler	793,450	991,813	1,190,175
Physical cleanup	16,221,647	20,277,059	24,332,471
Ash handling	302,267	377,833	453,400
Gas turbine	314,861	393,576	472,292
Balance of plant	6,108,307	7,635,383	9,162,460
Legal fee & permitting	545,803	682,254	818,705
General Facilities			
Road construction	1,480,378	1,850,473	2,220,567
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	3,006,719	3,758,398	4,510,078
Project contingency	3,611,821	4,514,776	5,417,731
Initial cost	1,534,999	1,918,748	2,302,498
SUB-TOTAL	41,265,030	51,581,285	61,897,543

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	5,124,205	6,405,257	7,686,808
Fixed O&M ($)	2,426,716	3,033,395	3,640,074
Land Lease	653,500	816,875	980,250
FIRST YEAR O&M	8,204,421	10,255,527	12,307,132

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Tree crops - Electricity

Island: Kauai	Location: Kaumakani	Project Code:	198,199,200
Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	104,011	Extent (harvested acres/year):	1,856
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Wood handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Road construction	1,209,086	1,511,358	1,813,630
Plantation lab	112,487	140,608	168,730
Equip. repair shop	1,451,440	1,814,300	2,177,160
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,637,822	4,547,277	5,456,733
Initial cost	1,477,554	1,846,942	2,216,331
SUB-TOTAL	41,493,595	51,866,993	62,240,392

TRANSMISSION

Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	4,535,382	5,669,228	6,803,074
Fixed O&M ($)	2,503,754	3,129,692	3,755,630
Land Lease	535,500	669,375	803,250
FIRST YEAR O&M	7,574,636	9,468,295	11,361,954

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Grass Crops - Electricity

Island: Kauai　　Location: Kaumakani　　Project Code: 204, 205, 206

Capacity (MW electricity):	25	Stage (current/future):	future
Resource (dry tons/year):	106,500	Extent (harvested acres/year):	3,236
Project Life (years):	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	168,630	153,300	137,970
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	168,630	153,300	137,970
CAPITAL COSTS			
Process Capital			
Feed handling and prep.	5,041,827	6,302,284	7,562,740
Gasification & compressor/precooler	7,379,597	9,224,496	11,069,396
Physical cleanup	560,203	700,254	840,304
Ash handling	570,976	713,720	856,464
Gas turbine	11,333,337	14,166,672	17,000,006
Balance of plant	5,117,239	6,396,549	7,675,858
Legal fee & permitting	547,008	683,760	820,512
General Facilities			
Engineering & overhead	3,055,019	3,818,773	4,582,528
Project contingency	3,360,521	4,200,651	5,040,781
Initial cost	1,483,362	1,854,203	2,225,043
SUB-TOTAL	38,449,089	48,061,362	57,673,632

TRANSMISSION			
Size (kV)	N/A	Distance (Miles):	0
Cost of Upgrade:	0		

ANNUAL EXPENSES			
Variable O&M ($)	5,314,480	6,643,100	7,971,720
Fixed O&M ($)	2,309,300	2,886,625	3,463,950
Land Lease	139,040	173,800	208,560
FIRST YEAR O&M	7,762,820	9,703,525	11,644,230

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: HYDRO

Island: Kauai | Location: Wailua River | Project Code: 234,235,236

Capacity (MW) 6.6
Resource(cfs, max) 365
Project Life (years) 50

Stage (current/future) current
Extent (ft of head) 262
Construction Time (years) 2.0

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	17200	16856	16684
Expected Losses (%)	2.5%	2.5%	2.5%
Net Energy (MWh/yr)	16770	16435	16267
CAPITAL COSTS			
Process Capital			
Intake Structure	$183,400	$192,570	$202,199
Penstock	$3,024,000	$3,175,200	$3,333,960
Tailrace	$89,600	$94,080	$98,784
Diversion Structure	$731,920	$768,516	$806,942
Powerhouse	$421,200	$442,260	$464,373
Turbine	$780,038	$819,040	$859,992
Generator	$1,170,059	$1,228,562	$1,289,990
Switchgear	$359,496	$377,471	$396,344
Equipment Installation	$91,000	$95,550	$100,328
Interconnection	$277,699	$291,584	$306,163
Legal Fees & Permitting	$141,120	$148,176	$155,585
Environmental Moinitoring	$63,000	$66,150	$69,458
General Capital Facilities			
Access Road	$67,200	$70,560	$74,088
Sable Storm Ditch	$84,000	$88,200	$92,610
Relocate USGS Gage	$22,400	$23,520	$24,696
Station Service	$79,110	$83,066	$87,219
Telecommunications	$35,000	$36,750	$38,588
Engineering Services			
Engineering	$609,619	$640,100	$672,105
Construction Management	$609,619	$640,100	$672,105
Post Construction Environmental	$63,000	$66,150	$69,458
Project Contingency	10.0%	10.0%	10.0%
SUB-TOTAL	$9,792,729	$10,282,365	$10,796,483
TRANSMISSION			
Cost of Upgrade	$1,000,000	$1,000,000	$1,000,000
ANNUAL EXPENSES			
Variable O&M	$81,250	$85,313	$89,578
Fixed O&M	$107,020	$112,371	$117,990
Rep. Spare Parts (Sinking Fund)	$9,793	$10,283	$10,797
Land Lease	$12,500	$13,125	$13,781
Federal Fees	$6,250	$6,563	$6,891
FIRST YEAR O&M	$216,813	$227,654	$239,036

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: HYDRO

Island: Kauai   Location: Wailua River   Project Code: 237, 238, 230

Capacity (MW) 6.6
Resource(cfs, max) 365
Project Life (years) 50

Stage (current/future) future
Extent (ft of head) 262
Construction Time (years) 2.0

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	17200	16856	16684
Expected Losses (%)	2.5%	2.5%	2.5%
Net Energy (MWh/yr)	16770	16435	16267
CAPITAL COSTS			
Process Capital			
Intake Structure	$183,400	$192,570	$202,199
Penstock	$3,024,000	$3,175,200	$3,333,960
Tailrace	$89,600	$94,080	$98,784
Diversion Structure	$731,920	$768,516	$806,942
Powerhouse	$421,200	$442,260	$464,373
Turbine	$780,038	$819,040	$859,992
Generator	$1,170,059	$1,228,562	$1,289,990
Switchgear	$359,496	$377,471	$396,344
Equipment Installation	$91,000	$95,550	$100,328
Interconnection	$277,699	$291,584	$306,163
Legal Fees & Permitting	$141,120	$148,176	$155,585
Environmental Moinitoring	$63,000	$66,150	$69,458
General Capital Facilities			
Access Road	$67,200	$70,560	$74,088
Sable Storm Ditch	$84,000	$88,200	$92,610
Relocate USGS Gage	$22,400	$23,520	$24,696
Station Service	$79,110	$83,066	$87,219
Telecommunications	$35,000	$36,750	$38,588
Engineering Services			
Engineering	$609,619	$640,100	$672,105
Construction Management	$609,619	$640,100	$672,105
Post Construction Environmental	$63,000	$66,150	$69,458
Project Contingency	10.0%	10.0%	10.0%
SUB-TOTAL	$9,792,729	$10,282,365	$10,796,483
TRANSMISSION			
Cost of Upgrade	$1,000,000	$1,000,000	$1,000,000
ANNUAL EXPENSES			
Variable O&M	$81,250	$85,313	$89,578
Fixed O&M	$53,510	$56,186	$58,995
Rep. Spare Parts (Sinking Fund)	$9,793	$10,283	$10,797
Land Lease	$12,500	$13,125	$13,781
Federal Fees	$6,250	$6,563	$6,891
FIRST YEAR O&M	$163,303	$171,468	$180,042

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Kauai   Location: Barking Sands   Project Code: 115, 116, 117

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	22,978	19,985	17,992
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**22,753**	**19,785**	**17,807**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$4,963,750	$5,225,000	$5,486,250
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3,747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$712,289	$712,289	$712,289
SUB-TOTAL	**$51,381,023**	**$56,517,711**	**$58,919,674**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$29,077	$32,308	$35,539
Fixed O&M	$46,313	$48,750	$51,188
Land Lease	$32,196	$33,890	$35,585
FIRST YEAR O&M	**$107,585**	**$114,948**	**$122,311**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Kauai — Location: Barking Sands — Project Code: 658, 659, 660

Capacity (MW)	10	Stage (current/future)	current
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	96,800
Project Life (years)	30	Construction Time (years)	2

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,735	22,383	20,151
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**25,483**	**22,159**	**19,943**
CAPITAL COSTS			
Process Capital			
PV Modules	$29,160,000	$32,400,000	$34,020,000
Array Structure & Foundations	$7,445,625	$7,837,500	$8,229,375
Power Condtioning Units	$2,486,250	$3,825,000	$4,016,250
Electrical & SCADA	$3,844,786	$3,883,622	$3,922,459
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$313,310	$329,800	$346,290
Legal Fees & Permitting	$524,384	$655,480	$819,350
General Facilities			
Roads and Grading	$614,156	$682,395	$750,635
Buildings and Fencing	$140,444	$156,049	$171,654
Engineering & Overhead	$3,747,787	$3;747,787	$3,747,787
Project Contingency	$4,371,853	$4,371,853	$4,371,853
Initial Costs	$712,289	$712,289	$712,289
SUB-TOTAL	**$53,862,898**	**$59,130,211**	**$61,662,799**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$43,616	$48,462	$53,308
Fixed O&M	$57,891	$60,938	$63,984
Land Lease	$32,196	$33,890	$35,585
FIRST YEAR O&M	**$133,702**	**$143,290**	**$152,877**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island: Kauai   Location: Barking Sands   Project Code: 118, 119, 120

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	23,810	20,709	17,608
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**23,577**	**20,502**	**17,427**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$3,573,900	$3,762,000	$3,950,100
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$498,671	$498,671	$498,671
SUB-TOTAL	**$36,066,818**	**$39,390,369**	**$41,094,551**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$27,232	$30,258	$33,284
Fixed O&M	$43,887	$46,197	$48,507
Land Lease	$25,494	$26,836	$28,178
FIRST YEAR O&M	**$96,614**	**$103,291**	**$109,968**

(rev. 11/02/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (tracking)

Island: Kauai Location: Barking Sands Project Code: 661, 662, 663

Capacity (MW)	10	Stage (current/future)	future
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	76,640
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	26,668	23,194	19,721
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	**26,407**	**22,962**	**19,518**
CAPITAL COSTS			
Process Capital			
PV Modules	$20,412,000	$22,680,000	$23,814,000
Array Structure & Foundations	$5,360,850	$5,643,000	$5,925,150
Power Condtioning Units	$1,118,813	$1,721,250	$1,807,313
Electrical & SCADA	$3,031,614	$3,062,236	$3,092,859
Substation	$502,014	$528,436	$554,857
Overseas Shipping	$281,979	$296,820	$311,661
Legal Fees & Permitting	$496,101	$620,127	$775,159
General Facilities			
Roads and Grading	$491,324	$545,916	$600,508
Buildings and Fencing	$130,601	$145,112	$159,624
Engineering & Overhead	$2,482,986	$2,482,986	$2,482,986
Project Contingency	$3,046,815	$3,046,815	$3,046,815
Initial Costs	$498,671	$498,671	$498,671
SUB-TOTAL	**$37,853,768**	**$41,271,369**	**$43,069,601**
TRANSMISSION			
Cost of Upgrade	**$0**	**$0**	**$0**
ANNUAL EXPENSES			
Variable O&M	$40,848	$45,387	$49,926
Fixed O&M	$54,859	$57,746	$60,633
Land Lease	$25,494	$26,836	$28,178
FIRST YEAR O&M	**$121,201**	**$129,969**	**$138,736**

(rev. 11/06/95)

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Kauai
Location: Barking Sands
Ownrshp: USN
Project Code: 340, 341, 342

Capacity (MW)	10	Stage (current/future)	Current
Resource (avg NIP,kWh/m2-day)	5.26	Extent (# of units)	400
Project Life (years)	30	Construction Time (years)	1.5
Geology Type	soil		

			OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION					
Gross Energy (MWh/yr)			17,868	17,017	15,316
Expected Losses (%)			3.3%	3.5%	3.8%
Capacity Factor (net)			20.0%	19.1%	17.2%
Net Energy (MWh/yr)			17,250	16,428	14,786
CAPITAL COSTS	1995$				
Process Capital			$/kWe,net	$/kWe,net	$/kWe,net
Support Structure			910	958	1006
Aximuth/Elevation Drives			222	234	246
Facets			194	204	214
Dish Control System			8	8	8
Stirling Engine/Generator			831	924	1016
Installation			317	334	351
Overseas Shipping			40	42	44
Legal Fees & Permitting			0.6	0.6	0.6
General Facilities					
Grubbing & Grading			113	126	145
Roads, buildings, fence			48	53	58
Engineering & Overhead			113	119	125
Project Contingency			252	265	278
Initial Costs			14	15	16
TOTAL CAPITAL COSTS		$/kWe,net	3,062	3,281	3,507
		$K	30,131	32,288	34,506

TRANSMISSION
Size (kV) --
Distance (Miles) --

Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	28.92	32.13	35.34
Variable O&M	cents/kWh	1.12	1.24	1.37
Land Lease	$K	51	57	63
FIRST YEAR O&M	$K	533	582	618
Total O&M, cents/kWh		2.85	3.17	3.48

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Dish Stirling

Island: Kauai
Location: Barking Sands
Ownrshp: USN
Project Code: 343, 344, 345

Capacity (MW)	10
Resource (avg NIP,kWh/m2-day)	5.26
Project Life (years)	30
Geology Type	soil

Stage (current/future)	Future
Extent (# of units)	400
Construction Time (years)	1.5

		OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION				
Gross Energy (MWh/yr)		18,762	17,868	16,081
Expected Losses (%)		3.1%	3.3%	3.6%
Capacity Factor (net)		21.0%	20.0%	18.0%
Net Energy (MWh/yr)		18,112	17,250	15,525
CAPITAL COSTS	1995$			
Process Capital		$/kWe,net	$/kWe,net	$/kWe,net
Support Structure		391	435	478
Aximuth/Elevation Drives		115	128	140
Facets		151	168	184
Dish Control System		5	5	6
Stirling Engine/Generator		412	458	503
Installation		301	334	367
Overseas Shipping		30	34	37
Legal Fees & Permitting		0.5	0.5	0.6
General Facilities				
Grubbing & Grading		102	113	130
Roads, buildings, fence		48	53	58
Engineering & Overhead		96	101	106
Project Contingency		189	199	209
Initial Costs		10	11	11
TOTAL CAPITAL COSTS	$/kWe,net	1,850	2,038	2,232
	$K	18,200	20,053	21,961

TRANSMISSION
Size (kV) –
Distance (Miles) –

Cost of Upgrade, $M		0	0	0
ANNUAL EXPENSES	1995$			
Fixed O&M	$/kW-yr	17.35	19.28	21.21
Variable O&M	cents/kWh	0.89	0.99	1.09
Land Lease	$K	51	57	63
FIRST YEAR O&M	$K	387	421	444
Total O&M, cents/kWh		1.88	2.09	2.30

03-Nov-95

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Kauai	Location	Anahola	Project Code	712, 713, 714

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	12.5	Extent (no. x dia. buoys)	180 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	315,213	315,213	315,213
Wave energy absorbtion efficiency	55%	45%	22%
Absorbed energy (MWh/yr)	171,972	140,535	70,267
Conversion & sea-to-shore transmission efficiency	76%	78%	81%
Landed energy at 100% availability (MWh/yr)	130,838	109,941	56,691
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	124,296	98,947	45,353
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	18,420,000	27,630,000	36,840,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,137,000	3,137,000	3,137,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	697,000	723,000	749,000
Process Capital Sub-Total	43,149,000	53,715,000	64,282,000
General Facilities	2,157,000	5,372,000	9,642,000
Engineering & Overhead	4,315,000	5,372,000	6,428,000
Project Contingency	4,962,000	6,446,000	8,035,000
Initial Costs	1,205,000	1,682,000	2,287,000
TOTAL PLANT COST	55,789,000	72,586,000	90,675,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	2,000,000	2,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	863,000	2,149,000	3,857,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,366,000	3,162,000	6,236,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Kauai	Location	Anahola	Project Code	709, 710, 711

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	12.5	Extent (no. x dia. buoys)	60 x 16m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	105,071	105,071	105,071
Wave energy absorbtion efficiency	55%	45%	22%
Absorbed energy (MWh/yr)	57,324	46,845	23,422
Conversion & sea-to-shore transmission efficiency	76%	78%	81%
Landed energy at 100% availability (MWh/yr)	43,597	36,635	18,894
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	41,417	32,972	15,115
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,080,000	10,620,000	14,160,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,648,000	1,648,000	1,648,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	630,000	641,000	651,000
Process Capital Sub-Total	16,598,000	20,728,000	24,859,000
General Facilities	830,000	2,073,000	3,729,000
Engineering & Overhead	1,660,000	2,073,000	2,486,000
Project Contingency	1,909,000	2,487,000	3,107,000
Initial Costs	462,000	646,000	878,000
TOTAL PLANT COST	21,458,000	28,007,000	35,059,000
ONSHORE TRANSMISSION UPGRADE	1,000,000	1,000,000	1,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	332,000	829,000	1,492,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	507,000	1,185,000	2,333,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Kauai	Location	Barking Sands	Project Code	706,707,708

Project size (MWe)	30	Stage (current/future)	future
Resource (kW/m, avg.)	14.8	Extent (no. x dia. buoys)	180 x 17m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	395,730	395,730	395,730
Wave energy absorbtion efficiency	24%	18%	9%
Absorbed energy (MWh/yr)	94,282	71,747	35,873
Conversion & sea-to-shore transmission efficiency	80%	80%	81%
Landed energy at 100% availability (MWh/yr)	75,174	57,547	29,002
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	71,415	51,793	23,201
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	20,613,000	30,919,000	41,225,000
Pelton turbine/generator	8,812,000	8,812,000	8,812,000
Balance of mechanical & electrical plant	3,356,000	3,356,000	3,356,000
Mooring hardware	4,480,000	4,480,000	4,480,000
Deployment	2,660,000	3,990,000	5,320,000
Sea-to-shore transmission	3,055,000	3,055,000	3,055,000
Onshore substation	1,586,000	1,586,000	1,586,000
Legal fees and permitting	702,000	731,000	760,000
Process Capital Sub-Total	45,265,000	56,930,000	68,596,000
General Facilities	2,263,000	5,693,000	10,289,000
Engineering & Overhead	4,526,000	5,693,000	6,860,000
Project Contingency	5,205,000	6,832,000	8,574,000
Initial Costs	1,263,000	1,777,000	2,428,000
TOTAL PLANT COST	58,522,000	76,925,000	96,747,000
ONSHORE TRANSMISSION UPGRADE	2,000,000	2,000,000	2,000,000
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	905,000	2,277,000	4,116,000
Amortized periodic replacements	503,000	1,014,000	2,379,000
FIRST YEAR O&M COST	1,408,000	3,291,000	6,495,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wave (heaving buoy, hose pump)

Island	Kauai	Location	Barking Sands	Project Code	703,704,705

Project size (MWe)	10	Stage (current/future)	future
Resource (kW/m, avg.)	14.8	Extent (no. x dia. buoys)	60 x 17m
Project life (years)	30	Construction time (years)	2

	OPTIMISTIC	NOMINAL	CONSV.
ENERGY PRODUCTION			
Incident wave energy (MWh/yr)	131,910	131,910	131,910
Wave energy absorbtion efficiency	24%	18%	9%
Absorbed energy (MWh/yr)	31,427	23,916	11,958
Conversion & sea-to-shore transmission efficiency	80%	80%	81%
Landed energy at 100% availability (MWh/yr)	25,053	19,179	9,666
Annual average availability	95%	90%	80%
NET LANDED ENERGY (MWh/yr)	23,800	17,261	7,733
CAPITAL COSTS ($)			
Buoy and damper plate fabrication	7,811,000	11,716,000	15,622,000
Pelton turbine/generator	2,937,000	2,937,000	2,937,000
Balance of mechanical & electrical plant	1,119,000	1,119,000	1,119,000
Mooring hardware	1,493,000	1,493,000	1,493,000
Deployment	1,161,000	1,741,000	2,322,000
Sea-to-shore transmission	1,580,000	1,580,000	1,580,000
Onshore substation	529,000	529,000	529,000
Legal fees and permitting	632,000	643,000	655,000
Process Capital Sub-Total	17,263,000	21,760,000	26,257,000
General Facilities	863,000	2,176,000	3,939,000
Engineering & Overhead	1,726,000	2,176,000	2,626,000
Project Contingency	1,985,000	2,611,000	3,282,000
Initial Costs	480,000	677,000	923,000
TOTAL PLANT COST	22,317,000	29,399,000	37,026,000
ONSHORE TRANSMISSION UPGRADE	0	0	0
ANNUAL EXPENSES ($)			
Ongoing fixed O&M costs	345,000	870,000	1,575,000
Amortized periodic replacements	175,000	356,000	842,000
FIRST YEAR O&M COST	520,000	1,227,000	2,417,000

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Kauai Location Anahola Project Code: 442,443,444
(leave blank)

Capacity (MW)	7	Stage (current/future)	Current
Resource (mph, avg.)	14.0	Extent (# of units)	28
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	9,694	8,813	7,932
Expected Losses (%)	20%	25%	30%
Net Energy (MWh/yr)	7,800	6,651	5,589
CAPITAL COSTS			
Process Capital			
Turbines & Towers	3,917,403	4,352,670	4,787,937
Foundations	273,596	276,360	279,124
Assembly & Checkout	180,894	182,721	184,548
Electrical Infrastructure	600,998	607,069	613,140
Sub-Station	385,480	389,374	393,267
Overseas Shipping	135,343	136,710	138,077
Legal Fees & Permitting	244,665	305,831	382,289
General Facilities			
Roads & Grading	54,470	55,020	55,570
Control System	61,647	62,269	62,892
Control Buildings	25,893	26,154	26,416
Central Building	39,723	44,137	55,171
Engineering & Overhead	592,011	643,831	697,843
Project Contingency	651,212	708,215	767,627
Initial Costs	375,685	390,418	407,555
SUB-TOTAL	$7,539,019	$8,180,779	$8,851,456
TRANSMISSION			
Cost of Upgrade	$1,000,000	$1,000,000	$1,000,000
ANNUAL EXPENSES			
Variable O&M	45,048	34,916	32,277
Fixed O&M	96,232	97,204	98,176
Land Lease	9,887	10,408	10,928
FIRST YEAR O&M	$151,167	$142,527	$141,380

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Kauai   Location Anahola   Project Code: 445,446,447
(leave blank)

Capacity (MW)	7	Stage (current/future)	Future
Resource (mph, avg.)	14.0	Extent (# of units)	23
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	11,953	10,866	9,780
Expected Losses (%)	20%	25%	30%
Net Energy (MWh/yr)	9,618	8,200	6,891
CAPITAL COSTS			
Process Capital			
Turbines & Towers	3,414,157	3,793,507	4,362,533
Foundations	220,245	222,470	224,694
Assembly & Checkout	147,105	148,591	150,077
Electrical Infrastructure	583,466	589,360	595,254
Sub-Station	385,480	389,374	393,267
Overseas Shipping	111,175	112,298	113,420
Legal Fees & Permitting	243,234	304,043	380,054
General Facilities			
Roads & Grading	45,114	45,570	46,026
Control System	50,132	50,638	51,145
Control Buildings	21,056	21,269	21,482
Central Building	39,723	44,137	55,171
Engineering & Overhead	526,089	572,126	639,312
Project Contingency	578,698	629,338	703,244
Initial Costs	366,098	378,343	399,866
SUB-TOTAL	$6,731,773	$7,301,064	$8,135,546
TRANSMISSION			
Cost of Upgrade	$1,000,000	$1,000,000	$1,000,000
ANNUAL EXPENSES			
Variable O&M	54,431	42,189	39,000
Fixed O&M	94,307	95,260	96,212
Land Lease	10,095	10,626	11,157
FIRST YEAR O&M	$158,833	$148,075	$146,370

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PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Kauai Location N. Hanapepe Project Code: 448,449,450 (leave blank)

Capacity (MW)	10	Stage (current/future)	Current
Resource (mph, avg.)	16.0	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	24,378	22,161	19,945
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	21,296	18,252	15,430
CAPITAL COSTS			
Process Capital			
Turbines & Towers	5,596,290	6,218,100	6,839,910
Foundations	436,590	441,000	445,410
Assembly & Checkout	258,420	261,030	263,640
Electrical Infrastructure	1,144,758	1,156,322	1,167,885
Sub-Station	550,686	556,248	561,810
Overseas Shipping	193,347	195,300	197,253
Legal Fees & Permitting	250,704	313,379	391,724
General Facilities			
Roads & Grading	101,871	102,900	103,929
Control System	88,066	88,956	89,846
Control Buildings	36,990	37,363	37,737
Central Building	85,121	94,579	118,223
Engineering & Overhead	874,284	946,518	1,021,737
Project Contingency	961,713	1,041,169	1,123,910
Initial Costs	509,294	527,664	551,868
SUB-TOTAL	$11,088,133	$11,980,529	$12,914,883
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	122,986	95,824	89,106
Fixed O&M	137,474	138,863	140,251
Land Lease	84,748	89,208	93,668
FIRST YEAR O&M	$345,207	$323,894	$323,026

HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Kauai Location N. Hanapepe Project Code: 451,452,453
(leave blank)

Capacity (MW)	10	Stage (current/future)	Future
Resource (mph, avg.)	16.0	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	30,187	27,443	24,699
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	26,372	22,602	19,107
CAPITAL COSTS			
Process Capital			
Turbines & Towers	4,898,573	5,442,858	6,259,287
Foundations	352,983	356,549	360,114
Assembly & Checkout	211,064	213,196	215,328
Electrical Infrastructure	1,116,197	1,127,471	1,138,746
Sub-Station	550,686	556,248	561,810
Overseas Shipping	159,511	161,123	162,734
Legal Fees & Permitting	248,681	310,851	388,564
General Facilities			
Roads & Grading	84,407	85,260	86,113
Control System	71,928	72,655	73,381
Control Buildings	30,211	30,516	30,822
Central Building	85,121	94,579	118,223
Engineering & Overhead	780,936	845,131	939,512
Project Contingency	859,030	929,644	1,033,463
Initial Costs	495,627	509,848	540,298
SUB-TOTAL	$9,944,955	$10,735,928	$11,908,396
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	149,251	116,288	108,136
Fixed O&M	134,724	136,085	137,446
Land Lease	86,902	91,476	96,050
FIRST YEAR O&M	$370,877	$343,849	$341,632

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PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island Kauai Location Port Allen Project Code: 454,455,456 (leave blank)

Capacity (MW)	5	Stage (current/future)	Current
Resource (mph, avg.)	15.4	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	11,433	10,394	9,354
Expected Losses (%)	20%	25%	30%
Net Energy (MWh/yr)	9,111	7,763	6,519
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,938,052	3,264,503	3,590,953
Foundations	195,426	197,400	199,374
Assembly & Checkout	129,210	130,515	131,820
Electrical Infrastructure	429,284	433,621	437,957
Sub-Station	275,343	278,124	280,905
Overseas Shipping	96,674	97,650	98,627
Legal Fees & Permitting	241,498	301,873	377,341
General Facilities			
Roads & Grading	39,501	39,900	40,299
Control System	44,033	44,478	44,923
Control Buildings	18,495	18,682	18,868
Central Building	39,723	44,137	55,171
Engineering & Overhead	444,724	485,088	527,624
Project Contingency	489,196	533,597	580,386
Initial Costs	326,325	336,752	349,892
SUB-TOTAL	$5,707,484	$6,206,318	$6,734,140
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	52,613	40,754	37,645
Fixed O&M	68,737	69,431	70,126
Land Lease	14,125	14,868	15,611
FIRST YEAR O&M	$135,475	$125,053	$123,382

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HAWAII ENERGY STRATEGY
PROJECT 3: RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Kauai	Location	Port Allen
		Project Code:	457,458,459 (leave blank)
Capacity (MW)	5	Stage (current/future)	Future
Resource (mph, avg.)	15.4	Extent (# of units)	16
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	13,729	12,481	11,233
Expected Losses (%)	20%	25%	30%
Net Energy (MWh/yr)	10,940	9,321	7,828
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,493,819	2,770,910	3,186,546
Foundations	153,214	154,762	156,309
Assembly & Checkout	102,334	103,368	104,402
Electrical Infrastructure	405,890	409,990	414,089
Sub-Station	275,343	278,124	280,905
Overseas Shipping	77,339	78,120	78,901
Legal Fees & Permitting	240,244	300,304	375,381
General Facilities			
Roads & Grading	32,017	32,340	32,663
Control System	34,874	35,227	35,579
Control Buildings	14,648	14,796	14,944
Central Building	39,723	44,137	55,171
Engineering & Overhead	386,944	422,208	473,489
Project Contingency	425,639	464,428	520,838
Initial Costs	319,344	327,515	343,521
SUB-TOTAL	$5,001,371	$5,436,227	$6,072,739
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	61,914	47,958	44,300
Fixed O&M	67,362	68,043	68,723
Land Lease	14,045	14,784	15,523
FIRST YEAR O&M	$143,321	$130,785	$128,546

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RENEWABLE ENERGY INTEGRATION PLAN

Phase 3: Renewable Energy Resource Assessment And Development Program

November 1995

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SECTION 1. INTRODUCTION AND BACKGROUND

RLA Consulting (RLA) has been retained by the State of Hawaii Department of Business, Economic Development, & Tourism (DBEDT) to conduct a Renewable Energy Resource Assessment and Development Program. This three-phase program is part of the Hawaii Energy Strategy (HES), which is a multi-faceted program intended to produce an integrated energy strategy for the State of Hawaii. This report summarizes the results of Phase 3 of the program, including a Renewable Energy Integration Plan for the State of Hawaii.

BACKGROUND

In Phase 1 of the Renewable Energy Resource Assessment and Development Program, suitable locations with development potential for renewable energy projects were identified. The emphasis for project identification was on utility-scale, grid-connected renewable energy projects. For each of the technologies under consideration, a potential project list was developed based on an elimination process of the available land on each of the six major Hawaiian islands: Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. For each island, geographic areas were identified in which resource potential exists, then an in-depth screening process was conducted that included consideration of factors such as land ownership, zoning, current and planned land uses, technology-specific development requirements, utility access and impact, environmental constraints, and public acceptance. Additional information on the methodology, assumptions, and results of Phase 1, along with a description of each project site are included in the Phase 1 report, *Renewable Energy Resource Assessment Plan.*

In Phase 2, detailed cost and performance estimates were developed for each of the potential projects identified in Phase 1. Tables 1-1 to 1-4 list the potential renewable energy projects and project sizes that were evaluated as part of this program. These projects represent viable development opportunities, with no foreseeable technical or institutional barrier, on each island and for each technology. Although no project sites are included in the database for either Lanai or Molokai, there is potential on these islands for small-scale renewable energy applications. On these islands, the size of the utility grid, the extent of the existing renewable energy projects, and the projections for demand growth limit consideration of any additional utility-scale renewable energy projects at this time. Small-scale applications for renewable energy technologies are discussed Section 5.

In order to estimate costs and performance for renewable energy projects in Hawaii, RLA compiled the most current cost and performance data for each of the renewable energy conversion technologies evaluated in the project. Technologies included wind, solar thermal (troughs and dishes), photovoltaics (fixed and tracking), biomass electricity (with energy crops and/or organic waste as a fuel source), biomass fuel (both methanol and ethanol), hydroelectric, wave, ocean thermal, and geothermal.

For most technologies, two conceptual plant designs were developed. One design was based on plant components that are commercially available for installation in 1995 (current technology). The other design was based on components that are realistically expected to be commercially deployed by the year 2005 (future technology). In the case of technologies that have not been commercially deployed, estimates were only made for the future scenario. For mature technologies in which no substantial technological advances are expected, estimates were developed for only the current scenario.

In order to account for the uncertainty in cost and resource projections, three estimates (representing optimistic, nominal, and conservative cases) were made for each potential project and for both states of technology development (current and future). As a result, a total of six cost and energy estimates were made for each potential project location and size for the majority of the technologies evaluated. The

Table 1-1. Potential Projects, Island of Hawaii

Technology	Project Location	Size (MW)
Wind	Kahua Ranch	5, 15
	Lalamilo Wells	3, 30, 50
	N. Kohala	5, 15
Solar Thermal		
Dishes	Keahole	30
	N. Kohala	5, 15
	Waikoloa	30
Trough	Keahole	30
	Waikoloa	30
Photovoltaic		
Fixed	Keahole	30, 50
	N. Kohala	5, 15
	Waikoloa	30, 50
Tracking	Keahole	30, 50
	N. Kohala	5, 15
	Waikoloa	30, 50
Biomass Electric		
Grass Crops	Hamakua Coast	25
	Hilo Coast	25
	Ka'u	25
Tree & Organic Waste	Hilo Coast	50
Tree Crops	Hamakua Coast	25
	Hilo Coast	25
Biomass Fuel-Methanol		
Grass Crops	Kaumakai	25 MGPY
Tree Crops	Hamakua Coast	25 MGPY
	Hilo Coast	25 MGPY
Hydro	Umauma Stream	13.8
Wave	Honokaa	10
	N. Kohala	10, 30
	Pepeekeo	10
Ocean Thermal	Keahole Point	60
Geothermal	Kilauea East Rift Zone	25, 50

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

Table 1-2. Potential Projects, Island of Maui

Technology	Project Location	Size (MW)
Wind	McGregor Point	30
	NW Haleakala	10, 30, 50
	Puunene	10, 30
	West Maui	10, 30, 50
Solar Thermal		
Dishes	Kahului	10, 30
	Kihei	10, 30
	Puunene	10, 30
Trough	Kahului	30
	Kihei	30
	Puunene	30
Photovoltaic		
Fixed	Kahului	10, 30
	Kihei	10, 30
	Puunene	10, 30
Tracking	Kahului	10, 30
	Kihei	10, 30
	Puunene	10, 30
Biomass Electric		
Organic Waste	Paia-Puunene	25
Grass Crops	Paia-Puunene	25, 50
Tree Crops	Paia-Puunene	50
Biomass Fuel-Ethanol		
Grass Crops	Paia-Puunene	25, 50 MGPY
Tree Crops	Paia-Puunene	25 MGPY
Biomass Fuel-Methanol		
Organic Waste	Paia-Puunene	25 MGPY
Grass Crops	Paia-Puunene	50 MGPY
Tree Crops	Paia-Puunene	50 MGPY
Wave	Lower Paia	10, 30, 60
	Opana Point	10, 30, 60
	Waiehu Point	10, 30

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

Table 1-3. Potential Projects, Island of Oahu

TECHNOLOGY	PROJECT LOCATION	SIZE (MW)
WIND	KAENA POINT	2, 15
	KAHUKU	30, 50, 80
SOLAR THERMAL		
DISHES	LUALUALEI	50
	N. EWA PLAIN	50
	PEARL HARBOR	50
TROUGH	LUALUALEI	80
	N. EWA PLAIN	80
	PEARL HARBOR	80
PHOTOVOLTAIC		
FIXED	LUALUALEI	10, 20, 50
	N. EWA PLAIN	10, 50
	PEARL HARBOR	10, 50
TRACKING	LUALUALEI	10, 20, 50
	N. EWA PLAIN	10, 50
	PEARL HARBOR	10, 50
BIOMASS ELECTRIC		
ORGANIC WASTE	BARBERS POINT	50
GRASS CROPS	WAIALUA	25
BIOMASS FUEL		
ORGANIC WASTE-ETHANOL	BARBERS POINT	25 MGPY
ORGANIC WASTE-METHANOL	BARBERS POINT	50 MGPY
WAVE	MAKAPUU	30, 60
	MOKAPU POINT	30
	N.E. COAST (UPPER)	30
	N.E. COAST (LOWER)	30
	WAIMANALO	30
	KAHUKU POINT	30, 60
OCEAN THERMAL	KAHE POINT	60

NOTE: PROJECT SIZE IS GIVEN IN MW OF INSTALLED CAPACITY EXCEPT BIOMASS-FUELS, WHICH ARE GIVEN IN MILLIONS OF GALLONS PER YEAR.

Table 1-4. Potential Projects, Island of Kauai

Technology	Project Location	Size (MW)
Wind	Anahola	7
	N. Hanapepe	10
	Port Allen	5
Solar Thermal		
Dishes	Barking Sands	10
Photovoltaic		
Fixed	Barking Sands	10
Tracking	Barking Sands	10
Biomass Electric		
Grass Crops	Kaumakani	25
	Lihue	25
Tree & Organic Waste	Kaumakani	50
Tree Crops	Kaumakani	25
	Lihue	25
Biomass Fuel-Methanol		
Tree Crops	Kaumakani	25 MGPY
	Lihue	25 MGPY
Hydro	Wailua River	6.6
Wave	Anahola	10, 30
	Barking Sands	10, 30

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

optimistic, nominal, and conservative cases differ from each other because of uncertainty in the energy projections, project costs, or a combination of both.

A user-friendly, Resource Supply Curve (RSC) computer model was then developed to calculate the levelized cost of energy (in 1995 dollars) for each project based on the Electric Power Research Institute Technical Assessment Guide (EPRI TAG) methodology, a common set of economic parameters, and the site-specific cost and performance estimates. The program calculates the cost of energy for each project and displays a graphical summary of the results of a specific query.

The RSC model provides a choice of evaluating projects based on two valuation methods and two basic financing options. The valuation methods include constant dollar analysis (no inflation) or current dollar analysis. Financing options include either utility or non-utility financing. To maximize the flexibility of the program, the user has the further option of changing the debt/equity ratios, the tax life, the inflation rate, the debt cost, the equity cost, the property tax, and the state and federal income tax credits to values other than the default values. Additional information on the use and assumptions incorporated into the RSC model, as well as the detailed cost and performance estimates for each project, are included in the Phase 2 report, *Development of Renewable Energy Resource Supply Curves.*

OBJECTIVES OF PHASE 3

The RSC program was developed to provide the user with a tool to compare various options under differing conditions. The objective of Phase 3 of the Renewable Energy Resource Assessment and Development Program is to concentrate on the integration and interpretation of the data by using the RSC model as an analysis tool. This reports presents the results of this analysis and draws conclusions for integrating renewable energy projects into the state's generation mix.

Another objective of Phase 3 was to collect additional wind and solar resource data from sites which appeared to have development potential but for which high-quality data were not publicly available. More than a year of data was collected at 8 wind sites and 5 solar sites. The cost and performance estimates for the wind and solar projects have been updated based on these new data. Summaries of the actual data that were collected under Phase 3, as well as summaries of the historical data that were utilized in the project, are included in a separate report.

REPORT ORGANIZATION

The report is organized into six sections. Following this introduction, Section 2 summarizes the results of the program for 1995, assuming current renewable energy technology and current economic conditions. Section 3 summarizes the results of the program for 2005, assuming future renewable energy technology and projections of future energy demand and costs. Section 4 discusses renewable energy project implementation in the State of Hawaii and includes a renewable energy integration plan for each island. The renewable energy integration plans are based on the 2005 results for each island given the constraints and limitations to project development that exist on that island. They represent a set of realistic goals for incorporating renewables into Hawaii's generation mix. Section 5 presents project implementation analyses for intermittent generating resources such as wind, solar, and wave projects. These analyses, which include load matching, capacity value, and time-of-day pricing, can impact the value an intermittent resource has to a utility system. Section 6 contains conclusions and recommendations.

SECTION 2. RESULTS FOR THE RESOURCE SUPPLY CURVE MODEL FOR 1995

This section discusses the renewable energy projects that appear to be economically and technically feasible for installation in 1995 under the set of assumptions presented. The assumptions in the RSC model may be changed to test other development scenarios or to adapt the results to changing conditions. Because these projects are not currently under development and are therefore not likely to be put in service in 1995, this evaluation is somewhat academic. However, the results highlight what might have been done if more information was available on the resource potential several years ago assuming the institutional requirements such as power purchase contracts, tax credits, land owner interest, and utility and/or independent power producer development interest also existed.

The 1995 results also provide a solid basis on which to plan future actions. Projects already shown to be economical, based on 1995 conditions, can be evaluated in more detail and placed in service over the next few years to provide cost savings for both the Hawaiian utilities and their customers. These projects can then form the basis for other, well characterized projects that will be economical by the year 2005.

ANALYSIS APPROACH

As previously discussed, the RSC model enables the user to evaluate the results from three possible cost and performance scenarios: nominal, conservative, and optimistic. The range in these estimates represents the variation in the technological development of each technology as well as the uncertainty in the resource. Hawaii can play a part in narrowing the range by participating in fundamental research or demonstration projects and by additional resource assessment; however, much of the variation is due to uncertainty in the pace of technology development over which the state generally has little influence.

In this section, results are presented for each of the three scenarios. Because the islands are not electrically interconnected, the analyses were carried out on an island-by-island basis. The nominal scenario, which reflects the most likely productivity and costs of the projects, is discussed as the base case.

Unless otherwise stated, utility financing and current state and federal tax credits were assumed for all 1995 projects. The base case analyses also include all required transmission costs to support the projects under consideration. The impacts of varying these assumptions are discussed later in this section. All analyses in this report were conducted in constant dollars.

To establish how much energy from renewable energy projects is cost-competitive with the local utility's current energy production costs, levelized cost of energy for each project is compared to the utility's avoided energy cost. Avoided energy cost represents the cost for the utility to generate additional electricity, it does not account for all potential utility impacts such as avoided or deferred system improvements or non-utility avoided costs (externalities). A vertical line representing this avoided cost was generated on the RSC graphs for each island. Projects to the left of this line on the RSC graphs represent projects that are cost-competitive (can be implemented at a levelized cost of energy that is lower than the current cost for the utility to supply the same amount of energy). Projects to the right of the line are more expensive than the utility's avoided energy cost. While the utility's avoided energy cost is expected to escalate over the lifetime of any proposed renewable energy project (further improving the comparison) the effect of this escalation has not been incorporated into the comparisons.

The annual benefits to Hawaii from implementing the viable renewable energy projects can be quantified by calculating the area under the curve and to the left of the vertical, avoided energy cost line. This benefit represents the net savings to the utility and its customers from using renewable energy projects rather than the generating units which form the basis of avoided energy costs.

In the following sections, the 1995 results are summarized for each island in terms of the amount of electricity that could be generated and the annual cost savings realized from implementing the viable projects. Results are provided for each development scenario by island. The impact of varying the assumptions is also evaluated. Note that although each of the projects discussed is viable independently, the entire list of projects for each island may not be viable as a group. For example, the total amount of electricity that could be generated from viable projects may be greater than the demand on that particular island, or more than the local utility can accommodate. In this section, all viable projects are presented and discussed. The constraints to developing the projects individually and as a group are discussed in more detail in Section 4. The results are combined into a realistic renewable energy implementation goal that considers the limitations of both the technology and the utility structure.

1995 RESULTS FOR THE ISLAND OF HAWAII

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Hawaii and their calculated cost of energy are included in Appendix A.

BASE CASE

Figure 2-1 shows the base case resource supply curve for the Island of Hawaii. For 1995, the average avoided energy cost for Hawaiian Electric Light Company (HELCO) was estimated to be approximately $0.0556/kWh. The avoided energy cost estimate was based on information provided in HELCO's most recent Integrated Resource Planning (IRP) document.

As shown in the graph, there are three viable wind energy projects on Hawaii that could be implemented in 1995 at a more economical cost than the utility's avoided energy cost: North Kohala, Lalamilo Wells, and Kahua Ranch. The graph shows the most cost-effective project size at each project site. Other project sizes evaluated at all three sites are also viable options, including a larger wind project at Kahua Ranch which requires a transmission line upgrade.

Even with just these three projects, the annual benefits to Hawaii are considerable. The area under the curve reflects the annual savings potential from implementing these three projects. Rather than spending $12.3 million per year (5.56 cents for each of the 221.6 million kWh), the island utility could instead spend $6.7 million for the same energy. The difference between these values is approximately $5.6 million, or the area under the curve (remember, however, that these projects may not be viable as a group, and the project owner(s) would likely require payment of more than their cost to generate).

OPTIMISTIC AND CONSERVATIVE CASES

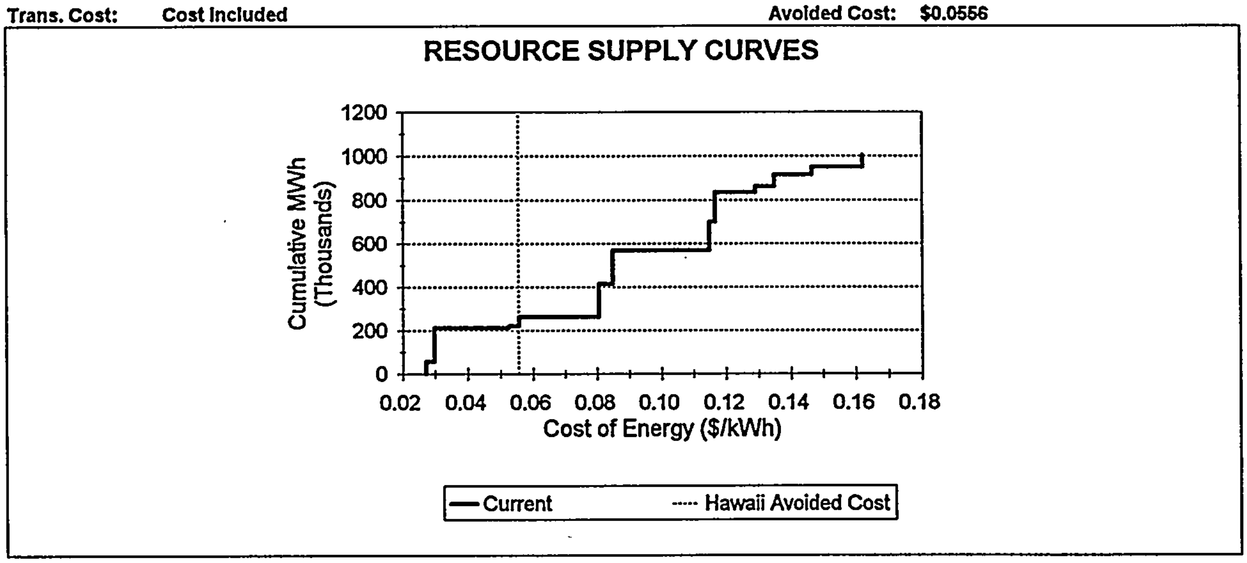
Under the optimistic assumptions in the model, one additional project on Hawaii, a 13.8 MW hydroelectric facility on Umauma Stream, is shown to be viable.

Under conservative assumptions, all the project sizes for the wind projects at both the Lalamilo Wells and North Kohala are still viable. This result is significant in that it illustrates the quality of the wind resource that is available at these two sites. Lalamilo Wells has long been identified as a good wind site and several wind energy development projects have been proposed for this site. The discovery of the high wind resource at the North Kohala site is one of the positive outcomes resulting from the monitoring program. Prior to the implementation of the monitoring program, there was no wind data available at this site.

1995 RESULTS FOR THE ISLAND OF MAUI

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Maui and their calculated cost of energy are included in Appendix B.

Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0556



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Hawaii	North Kohala	Current	Incl	Nominal	15	56,905	0.0272
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	50	154,183	0.0297
Wind		Hawaii	Kahua Ranch	Current	Incl	Nominal	5	10,516	0.0527
				Energy Produced below Avoided Cost				221,604	
				Annual Savings Potential from Renewables				$5,634,024	

Figure 2-1. 1995 Base Case Resource Supply Curve, Island of Hawaii

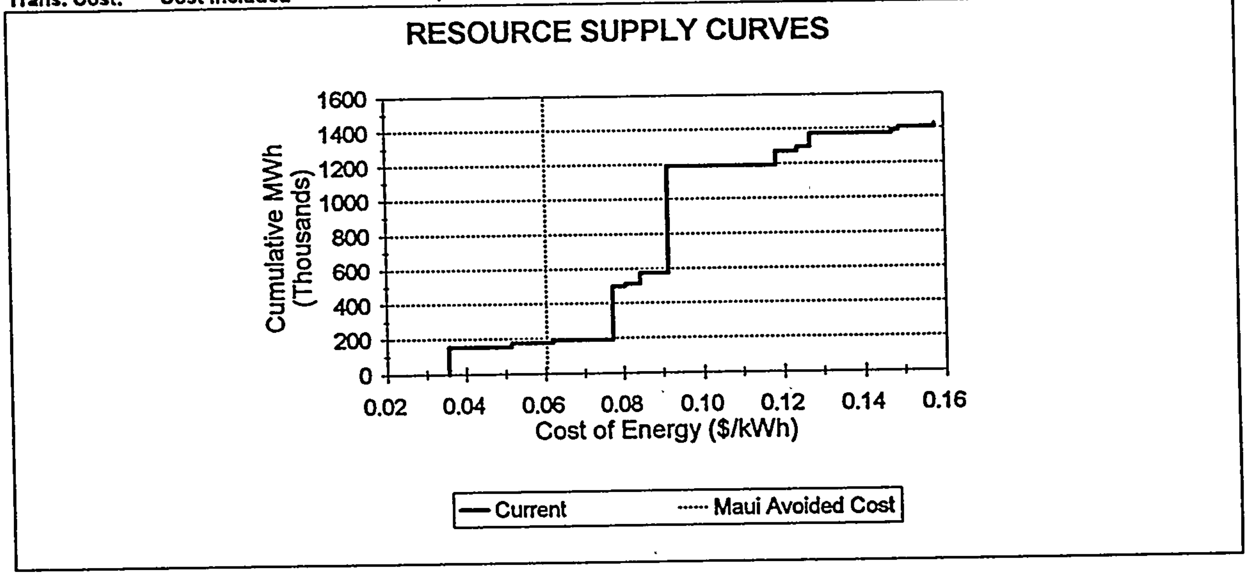
BASE CASE

Figure 2-2 shows the base case resource supply curve for the Island of Maui. For 1995, the avoided energy cost for Maui Electric (MECO) was estimated to be approximately $0.0604/kWh. The avoided energy cost estimate was based on information provided in MECO's most recent IRP document.

As shown in the graph, there are two viable renewable energy projects on Maui that could be implemented in 1995 at a more economical cost than the utility's avoided energy cost: a biomass electric project using organic waste as the fuel source and a wind project at McGregor Point. The costs associated with the biomass electric project assume that the project receives a revenue for waste disposal roughly equivalent to the tipping fees currently charged at the local landfill. As a result of this assumption, the biomass projects using organic waste as a fuel source are generally more cost-effective than other biomass projects.

The area under the curve reflects the annual savings potential from implementing these two projects. Rather than spending $10.5 million per year (6.04 cents for each of the 173.2 million kWh), the island utility could instead spend $6.6 million for the same energy. The difference between these values is approximately $3.9 million, or the area under the curve.

Island(s):	Maui	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0604



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Nominal	25	153,300	0.0357
Wind		Maui	McGregor Point	Current	Incl	Nominal	10	19,874	0.0515
				Energy Produced below Avoided Cost				173,174	
				Annual Savings Potential from Renewables				$3,967,581	

Figure 2-2. 1995 Base Case Resource Supply Curve, Island of Maui

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, two additional projects on Maui, a wind project on the northwest side of Haleakala and a biomass electric project using tree crops as the fuel source, become viable. For the NW Haleakala wind site, all three project sizes (10, 30, and 50 MW) are viable under the optimistic scenario.

Under conservative assumptions, only the biomass electric project using organic waste as a fuel source appears to be viable. The wind project at McGregor Point is not considered to be viable under the conservative scenario because the uncertainty of the wind resource is reflected in the conservative energy production estimates. Previous studies have indicated a high wind resource at this site; however, the existing data are of poor quality and it was not possible to monitor the site as part of the Phase 3 monitoring activities due to the disposition of the land lease holder at the time the monitoring program was organized. Additional monitoring could reduce the uncertainty associated with this project.

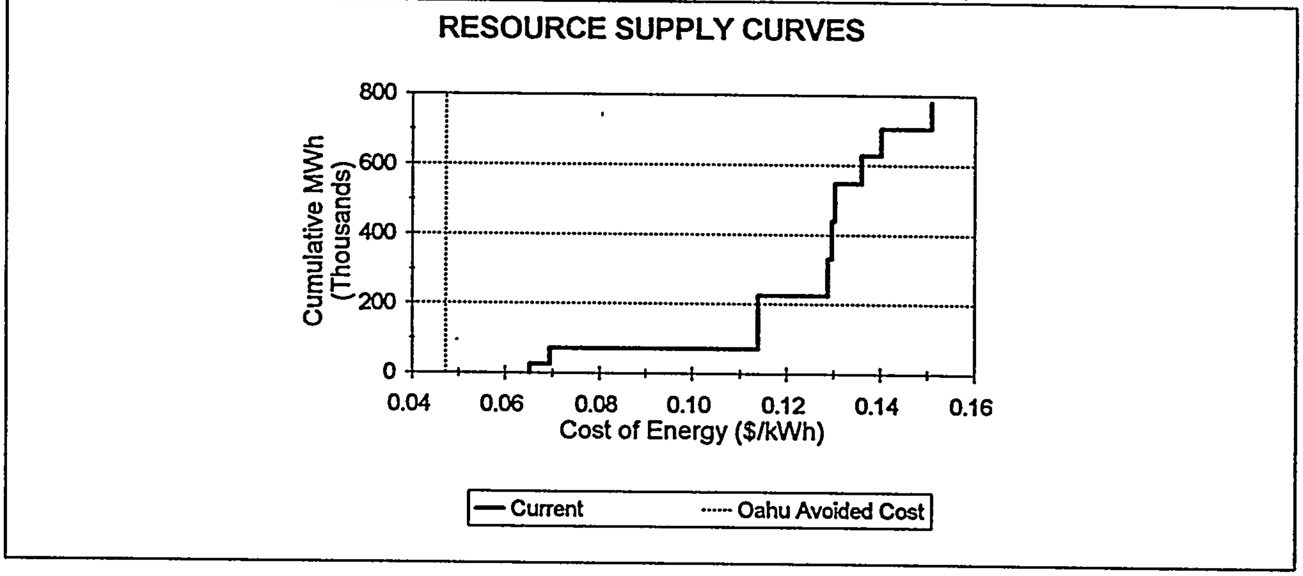
1995 RESULTS FOR THE ISLAND OF OAHU

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Oahu and their calculated cost of energy are included in Appendix C.

Base Case

Figure 2-3 shows the base case resource supply curve for the Island of Oahu. For 1995, the avoided energy cost for Hawaiian Electric Company (HECO) was estimated to be approximately $0.0473/kWh. The avoided energy cost estimate was based on information provided in HECO's most recent IRP document.

Island(s):	**Oahu**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Nominal**	**Tax Credits:**	**Included**
Stage:	**Current Technology**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0473**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
				Energy Produced below Avoided Cost				0	
				Annual Savings Potential from Renewables				$0	

Figure 2-3. 1995 Base Case Resource Supply Curve, Island of Oahu

As shown in the graph, there are no viable renewable energy projects on Oahu that could be implemented in 1995 at a more economical cost than the utility's avoided energy cost. This result is consistent with the fact that renewable energy projects are not currently under consideration on this island for 1995. An expansion or upgrade of the existing wind project at Kahuku may be more economical than shown in the analysis because some of the infrastructure to support a project already exists at that site; but this is not considered in the RSC database costs. Additional development has been proposed at this site.

Optimistic and Conservative Cases

Even under the optimistic assumptions in the model, there are no viable renewable energy projects on Oahu that could be implemented in 1995 at a cost more economical than the utility's avoided energy cost. The avoided energy cost on Oahu is the lowest in the state and the levels for 1995 used in the study are even lower than have been experienced in the past.

Wind projects at Kaena Point and Kahuku are the projects closest to being viable. Under optimistic assumptions, a 15 MW project at Kaena Point is approximately 12% more expensive than the utility's avoided energy cost. The next most cost-effective technology is a biomass electric project at the Waialua sugar facility. Although this project does not appear to be economical for 1995, additional benefit may be gained from implementing a project of this type so as to maintain a percentage of land on this island in agriculture. In addition, the biomass project would provide a dispatchable power source. Additional analyses, such as a cost sensitivity analysis assuming different fuel crops, may be warranted at this site.

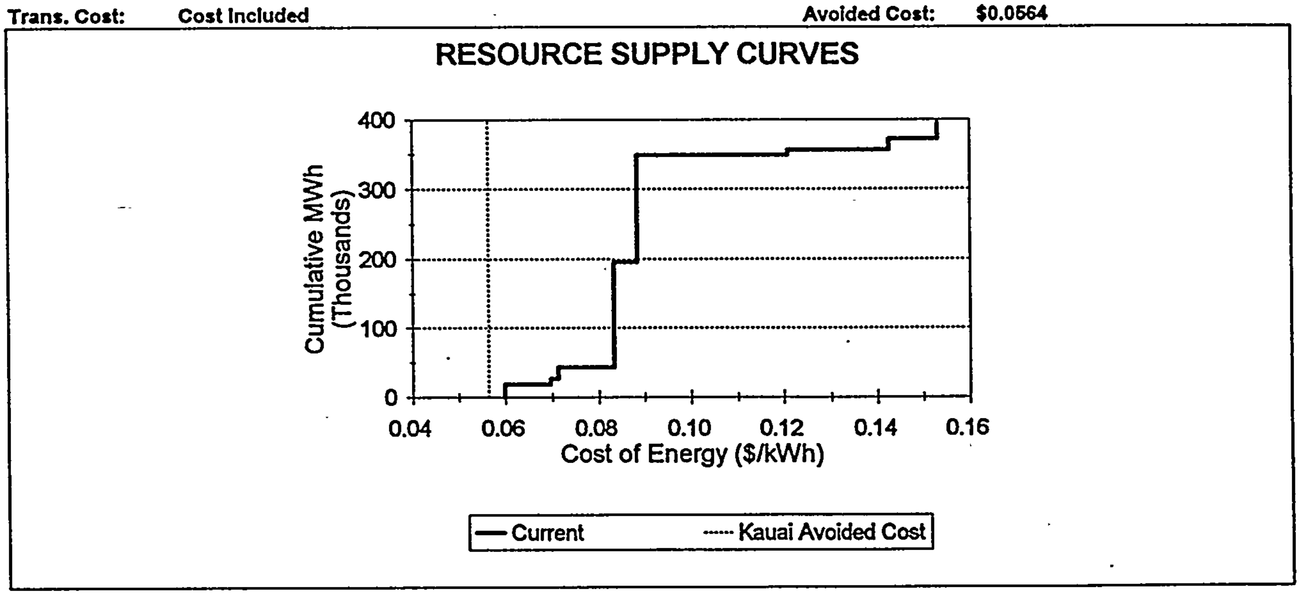
1995 RESULTS FOR THE ISLAND OF KAUAI

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Kauai and their calculated cost of energy are included in Appendix D.

BASE CASE

Figure 2-4 shows the base case resource supply curve for the Island of Kauai. For 1995, the avoided cost for Kauai Electric Company (KECO) was estimated to be approximately $0.0564/kWh. The avoided energy cost estimate was based on information provided in KECO's most recent IRP document.

Island(s):	Kauai	Valuation:	Constant Dollars
Technology:	All_Tech	Financing:	Utility
Certainty:	Nominal	Tax Credits:	Included
Stage:	Current Technology	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	$0.0564



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
				Energy Produced below Avoided Cost				0	
				Annual Savings Potential from Renewables				$0	

Figure 2-4. 1995 Base Case Resource Supply Curve, Island of Kauai

As shown in the graph, there are no viable renewable energy projects on Kauai that could be implemented in 1995 at a cost more economical than the utility's avoided energy cost. This result is due in part to the fact that utility demand, zoning restrictions, and competing land uses prevent consideration of large (greater than 10 MW) wind energy installations on Kauai.

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, two small wind projects appear to be viable: a 10 MW project north of Hanapepe and a 5 MW project near Port Allen. These two projects combine for a total of 30.4 million kWh and an annual savings potential of approximately $0.2 million.

The next most cost-effective technology for deployment in 1995 is a biomass electric project using tree crops. This 25 MW project is approximately 10% more expensive than the utility's avoided energy cost.

IMPACT OF VARYING THE 1995 BASE CASE ASSUMPTIONS

There are a number of policy-related uncertainties that are unrelated to the technology development scenario yet impact the base case results. These factors include financing terms and conditions, the inclusion of transmission upgrade costs, and the application of state and federal tax credits. For the nominal base case results and the optimistic and conservative results discussed above, the following factors were assumed:

1. Utility financing;
2. The inclusion of all costs associated with any additional transmission investment that might be required (some projects did not require transmission upgrades); and
3. Tax credits currently offered at federal and state levels.

To determine the impact that each of these assumptions has on the results, sensitivity studies were run for each of the following conditions:

1. Non-utility financing, which raises the cost of energy for the developer due to less favorable financing terms;
2. The assumption that the project does not have to pay for any additional transmission costs (due to the fact that upgrades may be underway for other reasons); and
3. No tax credits or accelerated depreciation are available to renewable energy projects due to changes in legislation.

The results of these sensitivity studies are summarized below.

NON-UTILITY FINANCING

If non-utility financing is assumed, the financial requirements for developing a power generation project are more demanding and the resulting costs of energy are higher. The higher cost of financing shifts the resource supply curves to the right, which in some cases results in project investments appearing less attractive when compared to the utility financing option. To evaluate the impact of varying this assumption, sensitivity studies were run for the nominal base cases using non-utility financing assumptions and leaving all other variables unchanged.

Figure 2-5 shows an example for the island of Hawaii which illustrates the shift in the graph due to non-utility financing. As shown on the graph, the projects which were viable under the utility financing option are still viable with non-utility financing. However, the net financial benefit, or the

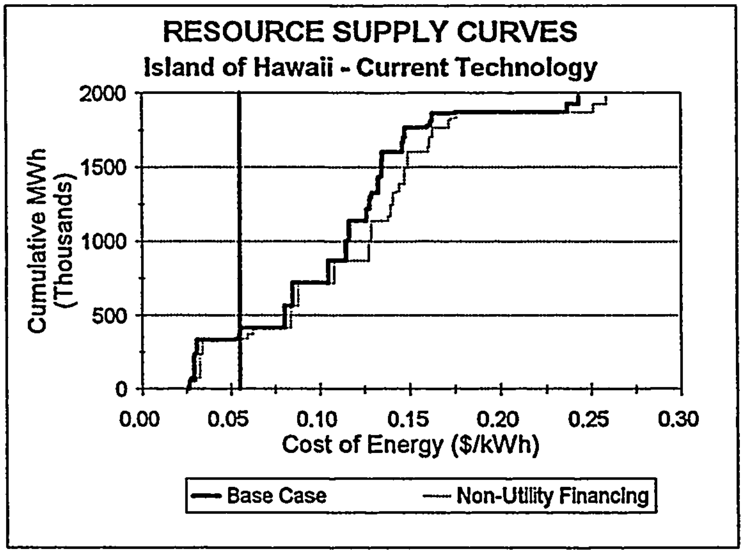


Figure 2-5. Sensitivity Analysis, Financing Options

area under the curve, is smaller. The same result holds true for the other islands. Projects with non-utility financing are still viable but have slightly higher costs and the annual savings potential for the island is smaller.

Transmission Investment Requirement

Eliminating the need for investment in transmission lines for projects that require transmission upgrades would obviously reduce the cost of energy from those projects. Sensitivity studies were run for the nominal base cases assuming any required upgrade costs were not included in the project costs and leaving all other variables unchanged. This scenario could result if the utility upgraded the transmission line for reasons other than to support the renewable energy project under consideration. For example, a 15 MW wind energy project at North Kohala requires a transmission upgrade; however, resort development and county water wells are also being considered in the North Kohala area and transmission upgrades to support these activities may be undertaken and paid for by another entity (or shared between interested parties). In some cases, more than one project may include costs for the same transmission line. For example, a new transmission line to support a project at North Kohala may result in sufficient capacity that a project at Kahua Ranch could also be developed without incurring any additional transmission costs.

This sensitivity analysis is not conducted to illustrate that transmission upgrades may not be necessary. It is just a question of who pays for the upgrade and whether these costs should be incurred by the project. In terms of cost of energy, the investment must be recovered regardless of who makes the investment and ultimately the electricity consumers pay for it in either case. The sensitivity shows only whether transmission investment is important enough to affect the developer's economics.

Figure 2-6 shows an example of this sensitivity study for the island of Hawaii. For the 1995 results, transmission costs only impact the viability of the larger Kahua Ranch wind energy project. Without including the required transmission costs, the larger Kahua Ranch project becomes viable under the nominal base case scenario.

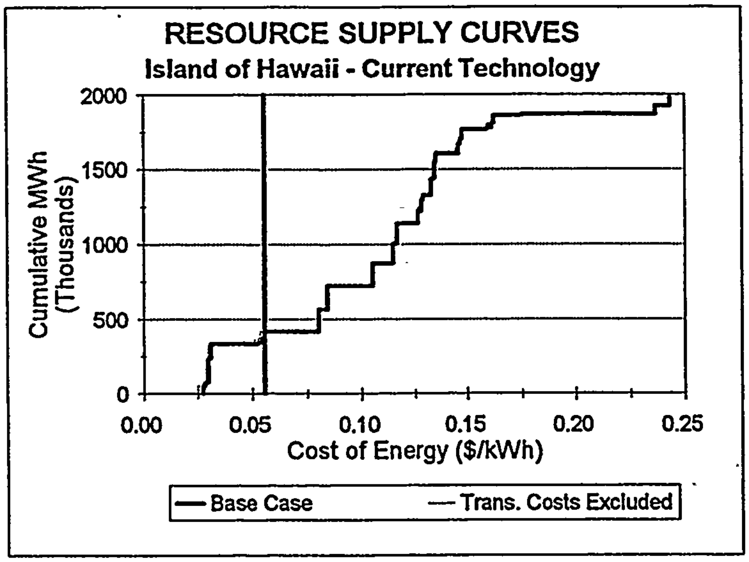


Figure 2-6. Sensitivity Analysis, Transmission Costs

TAX INCENTIVES

Both the federal government and the State of Hawaii offer tax credits for renewable energy projects. To determine whether these incentives impact the 1995 results, sensitivity studies were run for the nominal base cases assuming no tax credits or accelerated depreciation and leaving all other variables unchanged.

The loss of tax credits increases the cost of energy for the viable projects and decreases the net financial benefit significantly. Figure 2-7 shows an example for the island of Hawaii which illustrates the shift in the graph due to the loss of tax credits. Currently, wind, solar, and biomass are the only renewable technologies that receive tax credits.

SUMMARY OF 1995 RESULTS

Several conclusions are apparent from an examination of the RSC model results for 1995. The islands of Hawaii and Maui have the most opportunity in the near term for cost-competitive renewable energy project development. On Oahu, no projects appear to be immediately viable and on Kauai, limited opportunities exist, even under optimistic conditions. Table 2-1 summarizes the projected benefits or savings to the state from each of the cases that were analyzed.

On Hawaii, the three wind projects identified are extremely cost competitive with the current generating units. For all practical purposes, these projects are economic regardless of the assumptions that are made. Under optimistic assumptions, two more renewable energy projects can be implemented cost-effectively on this island. The amount of energy that can be supplied to Hawaii each year from wind power projects is noteworthy. In the nominal case, 221.6 million kWh can be generated which forms about approximately 23% of HELCO's generation.

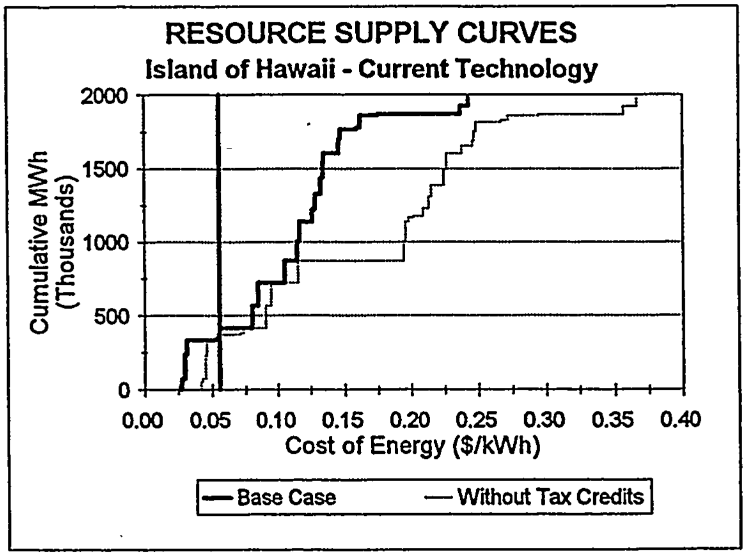


Figure 2-7. Sensitivity Analysis, Tax Credits

There are several reasons why these projects have not been implemented despite the favorable economics. First, wind projects have been implemented at some sites on Hawaii although most of them were installed more than ten years ago. These projects utilized older technology that was not as cost effective as today's wind turbines and, as a result, were not financially successful. This experience has resulted in a low confidence level in wind technology. Other issues limiting deployment are institutional and related to the utility operation. These issues are discussed further in Section 4.

Maui's two projects are not as cost competitive in that the loss of tax credits or the use of conservative assumptions eliminates the wind project and the biomass project becomes only marginally cost competitive. Optimistic assumptions increase the total number of viable projects to four, for a total generation of 617 million kWh annually.

On Oahu, no projects appear to be viable in the immediate future unless other factors are considered. For example, a wind project at Kahuku may be less expensive than projected because the infrastructure already exists.

On Kauai, only two projects appear to be cost competitive and only if optimistic assumptions are made. Given this result and the present over-capacity situation on Kauai, no large utility-scale projects are likely to be undertaken in the near future. Note that these projects are more feasible than previously thought and continuing investigations are warranted.

Small-scale renewable energy projects based on wind and solar technologies may turn out to be cost-effective on a distributed basis on Kauai and the other Hawaiian islands. This issue is addressed in Section 5.

Statewide, the only technologies that are economic in 1995 are wind, biomass electric, and hydro. Examination of the resource supply curves reveals that the other technologies considered in this project (solar thermal, photovoltaic, wave, geothermal, and ocean thermal) are not viable options in the immediate future. Some of these technologies look promising by 2005, as discussed in Section 3.

Table 2-1. Summary of Potential Benefits, 1995

1995
Tax Credits: Included
Data: Viable Projects

Valuation: Constant Dollars
Financing: Utility
Transmission Costs: Included

1995 Projected Utility Sales

Hawaii	957.0 GWh
Maui	881.0 GWh
Kauai	398.7 GWh

Renewable Energy Project					Optimistic			Nominal			Conservative		
Island	Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Hawaii	Hydro		Umauma Stream	13.8	41,019	$140,770	4.3%						
	Wind		Kahua Ranch	5	12,334	$175,709	1.3%	10,516	$30,315	1.1%			
	Wind		Kahua Ranch	15	35,735	$439,508	3.7%						
	Wind		Lalamilo Wells	3	12,109	$389,297	1.3%	10,366	$263,836	1.1%	8,750	$133,310	0.9%
	Wind		Lalamilo Wells	30	108,832	$3,405,760	11.4%	92,510	$2,272,534	9.7%	77,474	$1,113,879	8.1%
	Wind		Lalamilo Wells	50	181,386	$5,866,563	19.0%	154,183	$3,988,439	16.1%	129,123	$2,069,816	13.5%
	Wind		N. Kohala	5	21,693	$729,458	2.3%	18,569	$510,089	1.9%	15,676	$282,460	1.6%
	Wind		N. Kohala	15	66,183	$2,263,502	6.9%	56,905	$1,615,269	5.9%	48,105	$944,383	5.0%
Maui	Biomass Elec	org waste	Puunene	25	168,630	$7,480,431	19.1%	153,300	$3,791,131	17.4%	137,970	$101,831	15.7%
	Biomass Elec	tree crops	Pala-Puunene	50	337,260	$2,344,907	38.3%						
	Wind		McGregor Point	10	23,189	$453,811	2.6%	19,874	$176,450	2.3%			
	Wind		NW Haleakala	10	19,980	$224,193	2.3%						
	Wind		NW Haleakala	30	52,801	$140,771	6.0%						
	Wind		NW Haleakala	50	88,001	$424,815	10.0%						
Oahu	*No projects were viable for 1995 cost scenario.*												
Kaui	Wind		Port Allen	5	9,111	$16,524	2.3%						
	Wind		N. Hanapepe	10	21,296	$188,922	5.3%						

SECTION 3. RESULTS OF THE RESOURCE SUPPLY CURVE MODEL FOR 2005

This section of the report discusses the renewable energy projects that appear to be economically and technically feasible for installation in 2005. These projects represent viable opportunities for the State of Hawaii and should be considered in the planning processes of both the government and the utilities. Although the analyses were conducted for the year 2005, many of these projects will be economically cost competitive before that date. Therefore, the results of this analysis can be immediately utilized by decision makers in Hawaii's energy community. The information should provide valuable insight into the potential energy options for the future and assist in guiding long-range planning activities.

There are a significant number of potential renewable energy projects and technologies that become viable generating options by 2005. However, examination and evaluation of renewable energy projects in 2005 involves less certainty than for the year 1995. Although costs are lower for all the technologies, the ranges over which they could vary are significantly greater in the future. In addition, factors such as economic conditions, fuel costs, utility demand, and legislative changes are more difficult to estimate with a high confidence level. Despite this uncertainty, the analyses for 2005 are based on a realistic set of assumptions regarding future conditions and the results are consistent with industry expectations. Whenever possible, a conservative approach was taken in analyzing the data. As conditions change, the RSC model can be used to update the analyses appropriately.

ANALYSIS APPROACH

The results for 2005 were analyzed in a manner similar to the analysis for 1995. The range between the conservative, nominal, and optimistic scenarios is larger for projects in 2005, and therefore the results cover a broader range of possible development scenarios. In addition, several technologies that were considered to be unavailable in 1995 are included in the 2005 analysis.

As with the 1995 projects, utility financing was assumed for all 2005 projects. Because the federal tax production incentives for wind and biomass are scheduled to expire for projects installed after 1999, these tax credits were not included in the analyses in this section. The state and federal investment tax credits were included. Although it is possible that additional tax credits will be put in place, removing the production tax credits for biomass and wind result in a conservative estimate of the renewable energy contribution. The base case analyses also include all required transmission costs to support the projects under consideration and constant dollars are assumed.

The avoided energy cost estimates for 2005 were based on escalating the 1995 avoided energy costs by 5% annually. This escalation is intended to represent projected increases in fuel or other operating costs. Although the choice of escalation rate can significantly affect the 2005 results, a 5% escalation is considered to be reasonable. A discussion of the sensitivity of the avoided cost assumptions is included in this section. As with the 1995 analyses, a vertical line representing this avoided cost was generated on the resource supply curve graphs for each island and each scenario that was evaluated. Projects to the left of this line on the RSC graphs represent projects that can be implemented at a levelized cost of energy that is lower than the projected cost for the utility to supply the same amount of energy in 2005. Projects to the right of the line are more expensive than the utility's avoided cost.

Note that as less expensive renewable energy projects are incorporated into the generation mix, the avoided cost will go down if the utility owns the project. If an independent power producer develops the project, the project's impact on avoided energy cost will depend on the terms of the power purchase contract with the utility. In actuality, avoided cost is an inappropriate measure to evaluate projects in 2005 because the structure under which it has been calculated will not be valid in 2005 if renewable energy projects are incorporated in any significant quantity. Because of this uncertainty, the avoided cost estimate used in this analysis for each island is not meaningful as an absolute number. It is important only in its use as a measure by which to compare existing generation options and utility practices to the renewable energy generation options that could be implemented in the future.

In the sections below, the 2005 results are summarized for each island in terms of the amount of electricity that could be generated and the annual cost savings realized from implementing each of the viable projects. Because so many projects on each island appear to be viable in 2005, the annual cost savings are discussed in terms of individual projects rather than in terms of the entire group. The entire group of projects presented for each island is, in most cases, greater than could be installed, therefore, a sum of the cost savings is not as meaningful as it was for 1995 projects. Given that more opportunity for cost-effective renewable energy project development exists than can be developed, the number and size of the renewable energy projects that are ultimately installed will be determined based on factors other than cost. These factors include penetration limits for intermittent resources, load growth, or competing land uses and are discussed in the next section.

Results are provided for each development scenario by island. The impact of varying the assumptions is also evaluated. The 2005 results are further analyzed in Section 4 to develop a realistic renewable energy implementation goal.

2005 RESULTS FOR THE ISLAND OF HAWAII

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Hawaii and their calculated cost of energy are included in Appendix A.

BASE CASE

Figure 3-1 shows the base case 2005 resource supply curve for the island of Hawaii. For this analysis, the avoided cost for HELCO was projected to be $0.0906/kWh in 2005. As shown in the graph, there are eleven renewable energy projects on Hawaii that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. These projects include 3 wind projects, 1 geothermal project, 1 hydro project, 2 biomass electric projects utilizing tree crops and/or organic waste as the fuel source, 2 solar thermal dish projects, and 2 photovoltaic projects.

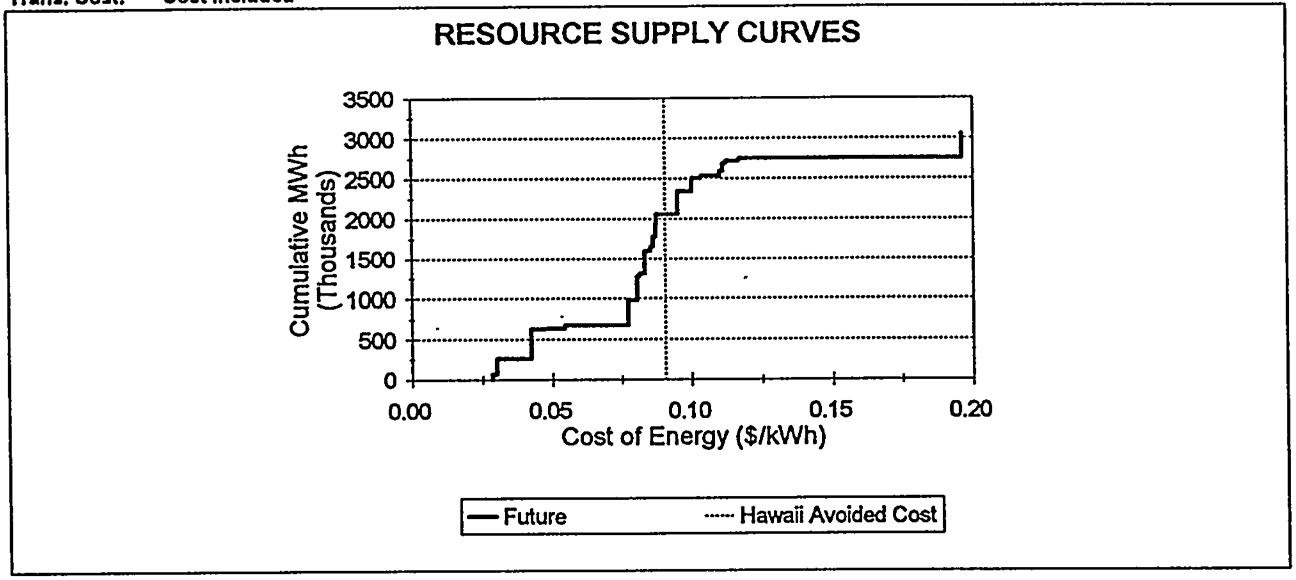
Although the graph shows only the most cost-effective project size, other project sizes are also viable at most of these sites under the nominal assumptions.

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, five additional projects on Hawaii were determined to be cost competitive. These projects include a biomass project utilizing grass crops as the fuel source, a photovoltaic project at North Kohala, and three wave energy projects along the northern coast of the island. The North Kohala project site is one of the few sites in the state that has both solar and wind energy potential. Three of the fifteen projects identified as being viable under optimistic conditions are located at this site: one solar thermal project, one photovoltaic project, and one wind project. Development of one of these projects is likely to exclude development of the other two projects. The project and technology that is most likely to be developed will depend on a number of factors. The wind energy project is likely to be cost effective at an earlier date and the anticipated wind loads on solar technology equipment may cause a problem for the solar designs (high wind loads can affect performance). On the other hand, utility grid stability (wind may be more intermittent than solar at this site) or public acceptance could result in development opportunities for the solar technologies.

Under conservative assumptions, only three wind projects and one hydroelectric project are still viable. These projects are the same projects that were determined to be cost effective in 1995 under the optimistic scenarios. This result implies that these projects are likely to become viable earlier than 2005. It also indicates that the costs are better defined for these technologies than for the other, less mature technologies. The higher confidence level in the costs results from the fact that numerous wind and hydroelectric facilities have been commercially developed at other locations.

Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0906



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Nominal	15	71,178	0.0288
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	50	192,086	0.0304
Geothermal		Hawaii	Kilauea	Future	Incl	Nominal	50	362,314	0.0425
Wind		Hawaii	Kahua Ranch	Future	Incl	Nominal	5	12,628	0.0480
Hydro		Hawaii	Umauma Stream	Future	Incl	Nominal	13.8	40,199	0.0544
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Nominal	50	306,600	0.0772
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Nominal	15	29,416	0.0814
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Nominal	30	55,125	0.0852
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Nominal	50	124,319	0.0862
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	153,300	0.0870
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Nominal	50	124,319	0.0873
				Energy Produced below Avoided Cost				1,471,484	
				Annual Savings Potential from Renewables				$41,558,949	

Figure 3-1. 2005 Base Case Resource Supply Curve, Island of Hawaii

Photovoltaic and solar thermal dish projects are close to being cost competitive under the conservative scenario. Several projects are within $0.01/kWh (approximately 6%) of the utility avoided cost under the conservative scenario.

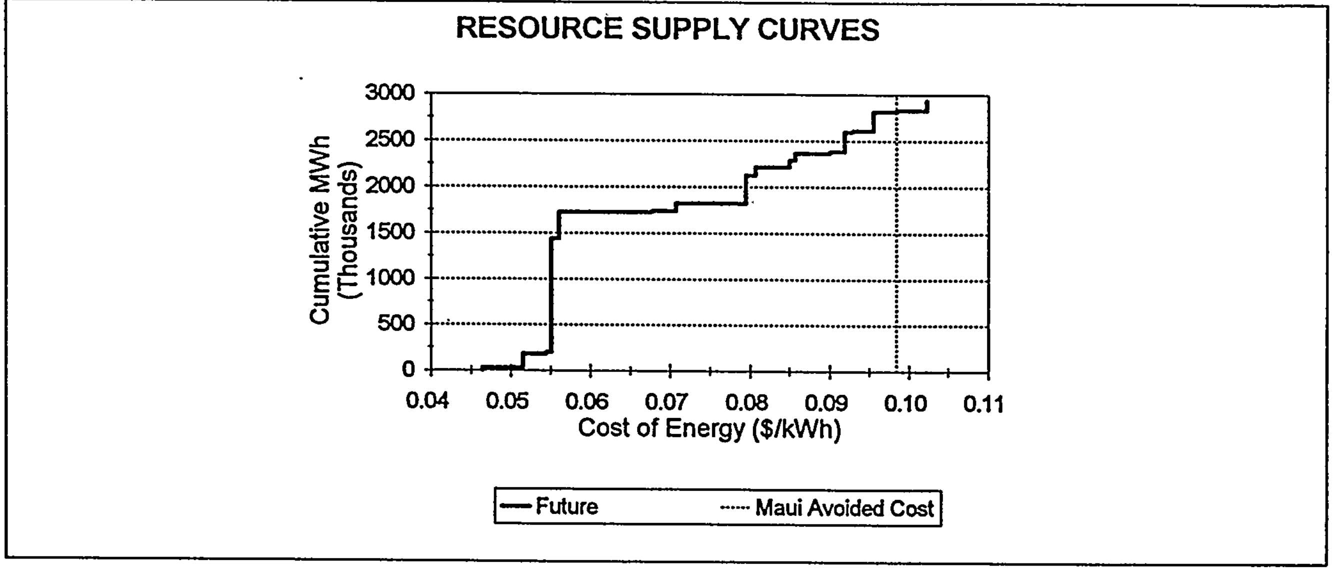
2005 RESULTS FOR THE ISLAND OF MAUI

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Maui and their calculated cost of energy are included in Appendix B.

BASE CASE

Figure 3-2 shows the base case resource supply curve of the island of Maui. For this analysis, the avoided cost for MECO was projected to be $0.0984/kWh in 2005. As shown in the graph, there are

Island(s):	Maui	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0984



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Maui	McGregor Point	Future	Incl	Nominal	10	24,611	0.0465
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Nominal	25	153,300	0.0515
Wind		Maui	NW Haleakala	Future	Incl	Nominal	10	21,205	0.0545
Wind		Maui	Puunene	Future	Incl	Nominal	10	15,784	0.0677
Wind		Maui	West Maui	Future	Incl	Nominal	50	77,546	0.0707
Biomass Elec	tree crops	Maui	Pala-Puunene	Future	Incl	Nominal	50	306,600	0.0795
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Nominal	30	82,893	0.0807
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Nominal	30	77,792	0.0850
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Nominal	30	78,159	0.0857
Solar Thermal	dish	Maui	Puunene	Future	Incl	Nominal	10	16,430	0.0901
Wave		Maui	Opana Point	Future	Incl	Nominal	60	211,984	0.0920
Solar Thermal	dish	Maui	Kihei	Future	Incl	Nominal	10	16,922	0.0929
Wave		Maui	Lower Paia	Future	Incl	Nominal	60	203,974	0.0956
				Energy Produced below Avoided Cost				1,287,200	
				Annual Savings Potential from Renewables				$23,487,236	

Figure 3-2. 2005 Base Case Resource Supply Curve, Island of Maui

13 renewable energy projects on Maui that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. These projects include four wind projects, two biomass electric projects utilizing tree crops and/or organic waste as the fuel source, two solar thermal dish projects, three photovoltaic projects, and two wave energy projects.

Although the graph shows only the most cost-effective project size, other project sizes are also viable at most of these sites.

Optimistic and Conservative Cases

Under the optimistic assumptions in the model, one additional wave project and one additional solar thermal dish project are shown to be viable. Smaller-sized projects at sites already included in the nominal scenario also become viable options.

Under conservative assumptions, the four wind projects (in all sizes) and a single biomass electric project using organic waste as a fuel source are the only cost-competitive options. These results include one more wind project than was viable under the optimistic scenario in 1995.

Biomass electric using tree crops as a fuel source, photovoltaic, and solar thermal projects are all within 10% of being cost competitive under the conservative scenario.

2005 RESULTS FOR THE ISLAND OF OAHU

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Oahu and their calculated cost of energy are included in Appendix C.

Base Case

Figure 3-3 shows the base case resource supply curve of the island of Oahu. For this analysis, the avoided cost for HECO was projected to be $0.077/kWh in 2005. As shown in the graph, there are two wind projects and one biomass electric project using organic waste as a fuel source that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. The wind projects include Kaena Point (at either 2 or 15 MW) and Kahuku (at either 30, 50, or 80 MW). Although all three size projects at Kahuku are viable options, the 30 MW project has the lowest cost of energy due to the cost of the transmission upgrade requirement. A 50 MW solar thermal dish project at Pearl Harbor is approximately 7% more expensive than the projected utility avoided cost.

Optimistic and Conservative Cases

Under the optimistic assumptions in the model, 15 projects appear to be viable. In addition to the base case project, 6 wave projects, 3 photovoltaic projects, 2 solar thermal projects, and 1 biomass electric project using grass crops as a fuel appear to be viable. The large number of wave projects and wave energy's cost effectiveness on Oahu (lowest cost of energy following the organic waste and wind energy projects) illustrate that wave energy offers significant contribution potential if the technology matures as expected under optimistic assumptions. A strong wave resource is available on the northeast coast of Oahu. Additional research on this technology and demonstration projects are needed to validate the cost and performance estimates.

All three viable projects identified in the base case remain viable under conservative assumptions. None of these projects were considered to be viable in 1995.

2005 RESULTS FOR THE ISLAND OF KAUAI

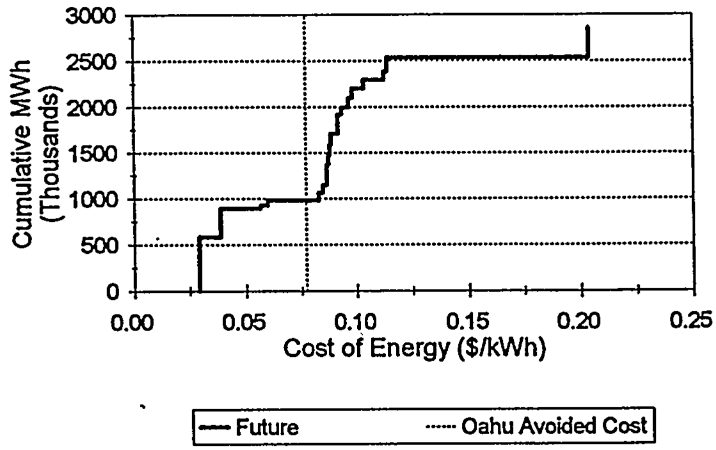
Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Kauai and their calculated cost of energy are included in Appendix D.

Base Case

Figure 3-4 shows the base case resource supply curve of the island of Kauai. For this analysis, the avoided cost for KECO was projected to be $0.0919/kWh in 2005. As shown in the graph, there are two wind projects, one hydroelectric, one solar thermal dish, and two biomass electric projects (one tree crops combined with one tree crop and organic waste) that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. Additional biomass projects are within 5% of the projected avoided cost.

Island(s):	Oahu	Valuation:	Constant Dollars
Technology:	All_Tech	Financing:	Utility
Certainty:	Nominal	Tax Credits:	Included
Stage:	Future Technology	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	$0.0770

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Nominal	50	306,600	0.0389
Wind		Oahu	Kaena Point	Future	Incl	Nominal	15	31,558	0.0567
Wind		Oahu	Kahuku	Future	Incl	Nominal	30	56,977	0.0597
				Energy Produced below Avoided Cost				395,135	
				Annual Savings Potential from Renewables				$13,307,378	

Figure 3-3. 2005 Base Case Resource Supply Curve, Island of Oahu

OPTIMISTIC AND CONSERVATIVE CASES

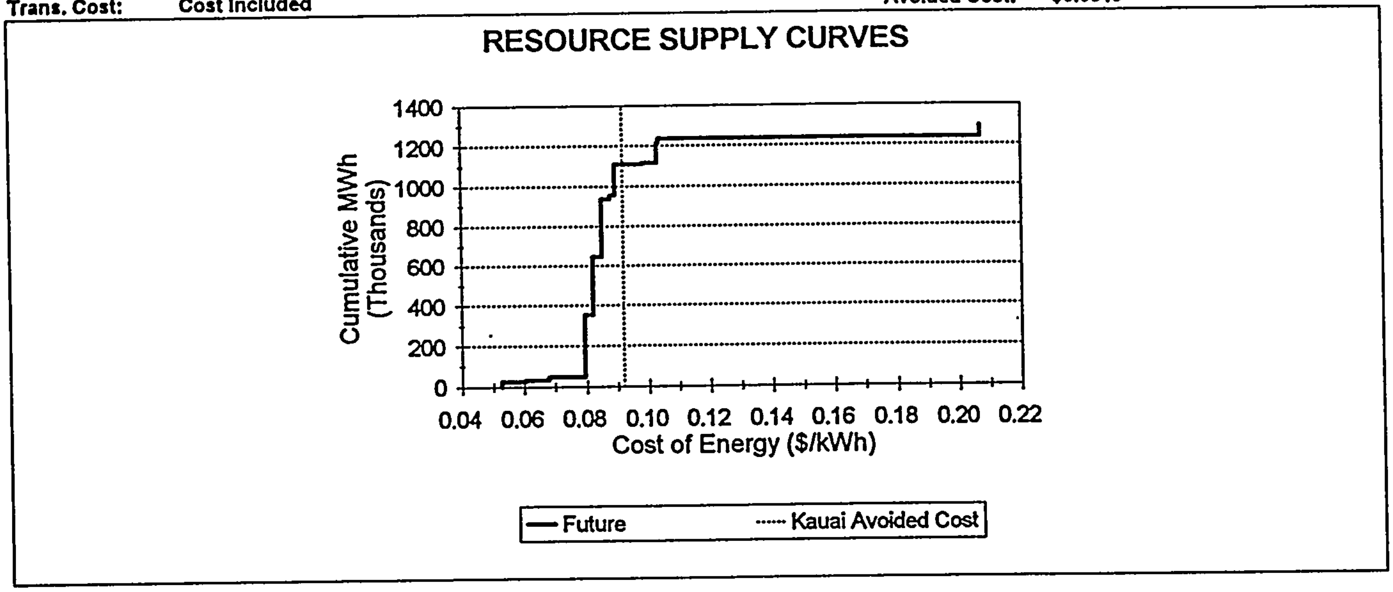
Under the optimistic assumptions in the model, nine projects appear to be viable. In addition to the base case projects, one wind project, one wave project, one photovoltaic project, and one solar thermal dish project become cost-effective under optimistic assumptions.

Under conservative assumptions, only the two wind projects and the hydroelectric project in the base case are still viable. The next most cost-effective project is approximately 15% more expensive than the projected avoided cost. This result again demonstrates the uncertainty associated with the developing technologies.

IMPACTS OF VARYING ASSUMPTIONS

The impacts of varying the assumptions for financing, the inclusion of transmission costs, and the consideration of tax credits are essentially the same as the impacts discussed in Section 2. Whether the project is utility financed or privately financed slightly increases the costs but does not cause viable projects to move to the right of the avoided cost line on the resource supply curves. The exclusion of transmission costs affects the same projects in the 2005 results as it did in the 1995 results.

Island(s):	**Kauai**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Nominal**	**Tax Credits:**	**Included**
Stage:	**Future Technology**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0919**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Kauai	N. Hanapepe	Future	Incl	Nominal	10	22,602	0.0529
Wind		Kauai	Port Allen	Future	Incl	Nominal	5	9,321	0.0603
Hydro		Kauai	Wailua River	Future	Incl	Nominal	6.6	16,435	0.0678
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Nominal	50	306,600	0.0794
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Nominal	10	17,250	0.0878
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Nominal	25	153,300	0.0894
				Energy Produced below Avoided Cost				525,508	
				Annual Savings Potential from Renewables				$5,870,070	

Figure 3-4. 2005 Base Case Resource Supply Curve, Island of Kauai

As in 1995, the exclusion of tax credits has the greatest impact on the 2005 results. The effects of removing the tax credit considerations in the sensitivity analysis are not as large for biomass and wind projects because the production tax incentives are not included for the 2005 analysis. For solar projects, however, removing tax credits from consideration has a significant impact on their viability.

Sensitivity of Results to Avoided Cost Assumptions

Visual examination of any of the resource supply curves quickly reveals the extent to which higher or lower avoided cost assumptions will affect the set of cost-competitive project choices. The impact of moving the vertical avoided cost line to the right (for higher avoided cost) or left (for lower avoided cost) can be easily seen on the graphs. The steeper the curve, the more sensitive the results are to the avoided cost assumptions.

On Hawaii, the flatness of the nominal RSC graph at the avoided-cost line intersection point illustrates that relatively small changes in the avoided cost assumptions will not affect the number of viable projects. On Oahu, however, the avoided cost line crosses the nominal RSC curve at a fairly steep part of the curve. Oahu results, therefore, are more sensitive to the avoided cost assumptions.

2005 RESULTS FOR BIOMASS FUELS

The RSC model also includes cost-of-energy estimates for a number of biomass fuel projects in 2005. Although these projects are not discussed in detail in this report, they also represent viable opportunities to use renewable resources to reduce the state's petroleum dependency. In the RSC model, the cost of energy for biomass fuel projects was converted into cents/kWh based on the heat content of the fuels to allow for comparison to electricity generating projects. In actual practice, these biomass projects will produce liquid fuels, not electricity, and will be competing for markets now dominated by gasoline. To evaluate whether these projects are economically viable options for the future, a more appropriate comparison can be made between the competing fuel alternatives.

Table 3-1 shows the estimated cost of the biomass fuels on a $/gallon basis for each of the projects contained in the RSC database. Estimates are provided for the optimistic, nominal, and conservative scenarios for both methanol and ethanol production projects. Note that these fuels have a different energy conversion efficiency from other fuel alternatives so a direct comparison of the costs presented in Table 3-1 to gasoline prices, for example, is not appropriate. It is also important to note that the published price (or pump price) of alternative fuels often includes hidden costs such as taxes and transportation. Although it is beyond the scope of this project to evaluate the costs of other fuel alternatives in detail, a few conclusions can be drawn regarding these energy conversion technologies.

Table 3-1. Cost Summary of Biomass Fuels

Island	Type	Location	MW	Cost per Gallon*		
				Optimistic	Nominal	Conservative
Hawaii	tree crops-methanol	Hamakua Coast	47	0.97	1.34	1.78
Hawaii	tree crops-methanol	Hilo Coast	47	1.00	1.38	1.84
Hawaii	grass crops-methanol	Kaumakai	47	1.15	1.58	2.10
Kauai	tree crops-methanol	Lihue	47	0.99	1.37	1.82
Kauai	tree crops-methanol	Kaumakani	47	1.03	1.42	1.89
Maui	org waste-methanol	Puunene	47	0.58	0.93	1.35
Maui	tree crops-methanol	Paia-Puunene	95	0.70	0.97	1.29
Maui	grass crops-methanol	Paia-Puunene	95	0.82	1.12	1.49
Maui	grass crop-ethanol	Paia-Puunene	141	1.42	1.95	2.60
Maui	tree crop-ethanol	Paia-Puunene	70	1.68	2.31	3.08
Oahu	org waste-methanol	Barbers Point	95	0.25	0.49	0.79
Oahu	org waste-ethanol	Barbers Point	70	0.77	1.30	1.94

* MGPY converted to MW based on the following equations.

1 MW = 1,000 MW x 8,760 hr/yr / 16.61 kWh/gal MeOH / 1,000,000 gal = 0.5274 MGPY MeOH

1 MW = 1,000 MW x 8,760 hr/yr / 24.70 kWh/gal EtOH / 1,000,000 gal = 0.3547 MGPY EtOH

A recently completed report from DBEDT entitled *Ethanol Production in Hawaii* by Dr. Robert Shleser indicates that the competitive production price per gallon for ethanol varies considerably depending on the potential markets for fuel ethanol. Competitive production prices range from a low of approximately $0.60 to more than $2.00 per gallon. The 2005 results from the model show optimistic production prices for ethanol ranging from $0.77 (with organic waste as the fuel source) to $1.42 per gallon (with grass crops as the fuel source). For an ethanol production facility using tree crops as the fuel source, costs ranged from a conservative estimate of $3.08 to an optimistic estimate of $1.68 per gallon. Similar comparisons can be made for methanol production projects. Although these numbers are far from conclusive, they illustrate that biomass fuels are in a realistic cost range to warrant further analysis.

SUMMARY OF 2005 RESULTS

Several conclusions are apparent from an examination of the RSC model results for 2005. Tables 3-2 through 3-5 summarize the energy production and potential benefits or savings to the state for all of the viable renewable energy projects for each island and development scenario. It is evident by the number of projects that all of the renewable energy generation cannot be utilized by the state's utilities. The renewable energy integration plans presented in the Section 4 prioritize and summarize the projects based on their cost effectiveness and ability to be incorporated into the state's utility grids.

Even under the conservative scenario, cost-effective projects exist on each island. For Hawaii and Maui, the number of projects under all scenarios is significant, again indicating the large potential for renewable energy on these islands.

On Oahu, large-scale projects are cost competitive under nominal and conservative conditions for biomass and wind technologies. Even though these projects are larger than considered on the other islands, they make a fairly small contribution in terms of energy production due to the larger demand on Oahu. Nonetheless, the annual savings potential to the state is significant even when other benefits are not considered.

On Kauai, projects are viable under all scenarios. The nominal cases include a wide diversity of technologies including biomass, hydro, solar thermal, and wind.

Table 3-2. Summary of Potential Benefit on Hawaii, 2005

2005 - Hawaii
Tax Credits: Excluded
Data: Viable Projects

Valuation: Constant Dollars
Financing: Utility
Transmission Costs: Included

2005 Projected Utility Sales
1,416.6 GWh

Renewable Energy Project				Optimistic			Nominal			Conservative		
Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Biomass Elec	grass crops	Ka'u	25	168,630	$2,982,819	11.9%						
Biomass Elec	tree & org waste	Hilo Coast	50	337,260	$12,146,639	23.8%	306,600	$4,106,177	21.6%			
Biomass Elec	tree crops	Hamakua Coast	25	168,630	$4,605,950	11.9%	153,300	$549,070	10.8%			
Geothermal		Kilauea	50	390,871	$22,596,693	27.6%	362,314	$17,434,626	25.6%	308,352	$8,181,736	21.8%
Geothermal		Kilauea	25	193,421	$10,101,330	13.7%	177,302	$6,982,903	12.5%	150,672	$2,006,646	10.6%
Hydro		Umauma Stream	13.8	41,019	$1,629,257	2.9%	40,199	$1,454,791	2.8%	39,788	$1,312,372	2.8%
Photovoltaic	tracking	Keahole	30	85,780	$1,304,617	6.1%						
Photovoltaic	tracking	Keahole	50	142,967	$3,061,806	10.1%	124,319	$408,330	8.8%			
Photovoltaic	tracking	N. Kohala	5	13,624	$11,736	1.0%						
Photovoltaic	tracking	N. Kohala	15	40,873	$317,418	2.9%						
Photovoltaic	tracking	Waikoloa	30	85,780	$1,228,256	6.1%						
Photovoltaic	tracking	Waikoloa	50	142,967	$2,934,504	10.1%	124,319	$408,330	8.8%			
Solar Thermal	dish	Keahole	30	57,882	$971,051	4.1%	55,125	$294,975	3.9%			
Solar Thermal	dish	N. Kohala	5	10,399	$179,801	0.7%	9,904	$59,957	0.7%			
Solar Thermal	dish	N. Kohala	15	30,886	$609,856	2.2%	29,416	$269,194	2.1%			
Wave		Honokaa 2A	10	42,134	$1,326,554	3.0%						
Wave		N. Kohala	10	39,276	$906,723	2.8%						
Wave		N. Kohala	30	117,856	$3,699,708	8.3%						
Wave		Pepeekeo 2E	10	40,968	$1,210,619	2.9%						
Wind		Kahua Ranch	5	14,811	$753,456	1.0%	12,628	$537,485	0.9%	10,612	$307,122	0.7%
Wind		Kahua Ranch	15	44,699	$2,221,414	3.2%	38,021	$1,573,746	2.7%	31,865	$886,868	2.2%
Wind		Lalamilo Wells	3	15,147	$976,880	1.1%	12,966	$774,079	0.9%	10,945	$561,126	0.8%
Wind		Lalamilo Wells	30	136,131	$8,709,915	9.6%	115,714	$6,852,583	8.2%	96,907	$4,925,705	6.8%
Wind		Lalamilo Wells	50	225,977	$14,637,464	16.0%	192,086	$11,564,058	13.6%	160,865	$8,379,774	11.4%
Wind		N. Kohala	5	26,048	$1,702,148	1.8%	22,298	$1,357,940	1.6%	18,823	$997,994	1.3%
Wind		N. Kohala	15	83,049	$5,469,135	5.9%	71,178	$4,398,300	5.0%	60,171	$3,282,410	4.2%

Table 3-3. Summary of Potential Benefit on Maui, 2005

2005 - Maui
Tax Credits: Excluded
Data: Viable Projects

Valuation: Constant Dollars
Financing: Utility
Transmission Costs: Included

2005 Projected Utility Sales
1,042.7 GWh

Renewable Energy Project				Optimistic			Nominal			Conservative		
Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Biomass Elec	org waste	Puunene	25	168,630	$11,543,043	16.2%	153,300	$7,901,769	14.7%	137,970	$2,822,858	13.2%
Biomass Elec	tree crops	Pala-Puunene	50	337,260	$13,681,730	32.3%	306,600	$5,788,622	29.4%			
Photovoltaic	tracking	Kahului	10	31,776	$930,580	3.0%	27,632	$327,256	2.7%			
Photovoltaic	tracking	Kahului	30	95,327	$3,208,893	9.1%	82,893	$1,465,341	7.9%			
Photovoltaic	tracking	Kihei	10	29,961	$749,709	2.9%	26,053	$169,354	2.5%			
Photovoltaic	tracking	Kihei	30	89,883	$2,666,376	8.6%	78,159	$991,933	7.5%			
Photovoltaic	tracking	Puunene	10	29,821	$761,549	2.9%	25,931	$184,308	2.5%			
Photovoltaic	tracking	Puunene	30	89,461	$2,704,904	8.6%	77,792	$1,040,066	7.5%			
Solar Thermal	dish	Kahului	10	16,735	$219,054	1.6%						
Solar Thermal	dish	Kihei	10	17,768	$317,702	1.7%	16,922	$93,244	1.6%			
Solar Thermal	dish	Puunene	10	17,252	$350,073	1.7%	16,430	$137,141	1.6%			
Solar Thermal	dish	Puunene	30	51,234	$815,217	4.9%	48,795	$170,062	4.7%			
Wave		Lower Paia	10	42,635	$1,656,209	4.1%						
Wave		Lower Paia	30	127,957	$5,766,292	12.3%						
Wave		Lower Paia	60	255,885	$12,277,127	24.5%	203,974	$578,513	19.6%			
Wave		Opana Point	10	44,283	$1,818,372	4.2%						
Wave		Opana Point	30	132,906	$6,253,273	12.7%	106,004	$129,071	10.2%			
Wave		Opana Point	60	265,780	$13,250,795	25.5%	211,984	$1,366,697	20.3%			
Wave		Waiehu Point	10	42,269	$1,581,201	4.1%						
Wave		Waiehu Point	30	126,887	$5,613,846	12.2%						
Wind		McGregor Point	10	28,715	$1,152,551	2.8%	24,611	$1,277,500	2.4%	20,805	$816,035	2.0%
Wind		NW Haleakala	10	24,741	$1,316,885	2.4%	21,205	$931,420	2.0%	17,926	$517,772	1.7%
Wind		NW Haleakala	30	66,045	$3,100,800	6.3%	56,140	$1,937,798	5.4%	47,015	$703,622	4.5%
Wind		NW Haleakala	50	109,635	$5,326,333	10.5%	93,192	$3,457,891	8.9%	78,045	$1,475,870	7.5%
Wind		Puunene	10	18,501	$794,278	1.8%	15,784	$485,012	1.5%	13,275	$148,568	1.3%
Wind		Puunene	30	53,073	$1,987,891	5.1%	45,113	$1,087,976	4.3%	37,781	$114,265	3.6%
Wind		West Maui	10	18,069	$681,186	1.7%	15,416	$374,341	1.5%	12,965	$40,254	1.2%
Wind		West Maui	30	54,754	$2,160,169	5.3%	46,715	$1,243,842	4.5%	39,288	$250,678	3.8%
Wind		West Maui	50	90,891	$3,660,130	8.7%	77,546	$2,148,795	7.4%	65,218	$514,476	6.3%

Table 3-4. Summary of Potential Benefit on Oahu, 2005

2005 - Oahu
Tax Credits: Excluded
Data: Viable Projects

Valuation: Constant Dollars
Financing: Utility
Transmission Costs: Included

2005 Projected Utility Sales
8,550.9 GWh

Renewable Energy Project				Optimistic			Nominal			Conservative		
Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Biomass Elec	org waste	Barber's Point	50	337,260	$19,415,948	3.9%	306,600	$11,677,840	3.6%	275,940	$3,939,732	3.2%
Photovoltaic	tracking	Lualualei	20	51,371	$3,932	0.6%						
Photovoltaic	tracking	Lualualei	50	128,426	$901,656	1.5%						
Photovoltaic	tracking	N. Ewa Plain	50	128,426	$795,581	1.5%						
Photovoltaic	tracking	Pearl Harbor	50	128,426	$846,393	1.5%						
Solar Thermal	dish	Lualualei	50	84,957	$299,260	1.0%						
Solar Thermal	dish	Pearl Harbor	50	89,197	$457,192	1.0%						
Wave		Kahuku Point	30	132,640	$3,588,223	1.6%						
Wave		Kahuku Point	60	265,253	$7,537,155	3.1%						
Wave		Makapuu	30	139,714	$4,074,677	1.6%						
Wave		Makapuu	60	279,377	$8,646,189	3.3%						
Wave		Mokapu Point	30	122,913	$2,734,842	1.4%						
Wave		NE Coast 2A	30	129,936	$3,368,929	1.5%						
Wave		NE Coast 2C	30	126,276	$3,098,195	1.5%						
Wave		Waimanalo Bay	30	111,677	$1,950,993	1.3%						
Wind		Kaena Point	2	4,673	$123,986	0.1%	4,002	$61,156	0.0%			
Wind		Kaena Point	15	36,966	$1,107,657	0.4%	31,558	$642,174	0.4%	26,560	$129,058	0.3%
Wind		Kahuku	30	67,029	$1,869,607	0.8%	56,977	$987,364	0.7%	$47,716	$17,197	0.6%
Wind		Kahuku	50	111,268	$3,019,081	1.3%	94,581	$1,564,323	1.1%			
Wind		Kahuku	80	178,298	$3,930,812	2.1%	151,558	$1,603,709	1.8%			

Table 3-5. Summary of Potential Benefit on Kauai, 2005

2005 - Kauai
Tax Credits: Included
Data: Viable Projects

Valuation: Constant Dollars
Financing: Utility
Trans. Cost: Cost Included

2005 Projected Utility Sales
568.3 GWh

Renewable Energy Project				Optimistic			Nominal			Conservative		
Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Biomass Elec	tree & org waste	Kaumakani	50	337,260	$12,069,774	59.3%	306,600	$3,838,465	53.9%			
Biomass Elec	tree crops	Lihue	25	168,630	$4,538,343	29.7%	153,300	$389,827	27.0%			
Hydro		Wailua River	6.6	16,770	$475,719	3.0%	16,435	$395,840	2.9%	16,267	$328,852	2.9%
Photovoltaic	tracking	Barking Sands	10	26,407	$240,253	4.6%						
Solar Thermal	dish	Barking Sands	10	18,112	$284,532	3.2%	17,250	$70,213	3.0%			
Wave		Anahola	10	41,417	$1,182,176	7.3%						
Wave		Anahola	30	124,296	$4,609,212	21.9%						
Wind		Anahola	7	9,618	$111,449	1.7%						
Wind		N. Hanapepe	10	26,372	$1,263,460	4.6%	22,602	$881,293	4.0%	19,107	$469,261	3.4%
Wind		Port Allen	5	10,940	$465,153	1.9%	9,321	$294,433	1.6%	7,828	$108,881	1.4%

SECTION 4. PROJECT IMPLEMENTATION ANALYSES FOR INTERMITTENT RENEWABLE ENERGY RESOURCES

In evaluating the renewable energy generating options, it is important to consider the value of the energy to a utility as well as the cost of generation. Utilities commonly consider intermittent generating resources, such as wind, solar, and wave energy, to be less valuable than firm generating resources because intermittent resources are non-dispatchable. The value of the resource to the utility has significant impacts on the likelihood of project implementation. If these intermittent resources can be shown to have some quantifiable value to the utility, the likelihood of implementation is increased.

The following sections provide summaries of analyses aimed at identifying the value of these intermittent resources. These analyses include utility load matching with renewable energy project output on a diurnal and seasonal basis, determination of capacity value, and a comparison of the impact of time-of-day delivery and pricing scenarios for each island. Renewable energy projects also have value in their environmental and societal benefits, reduced fuel risk, short lead time, and modularity. Although these attributes should be fully considered in any planning process, their quantification is beyond the scope of this study.

For each of the analyses and results presented below, typical outputs or representative projects are discussed for wind, solar, and wave energy technologies. The other technologies evaluated in this study are considered to be firm generating resources. A differentiation between solar thermal and photovoltaics is not generally made because the output from both types of projects is similar on a diurnal and seasonal basis.

UTILITY LOAD MATCHING

As part of Phase 3, RLA developed diurnal and seasonal energy estimates for all the intermittent renewable energy projects contained in the RSC database. Diurnal estimates were developed on both a monthly and annual basis. A user-friendly computer model (separate from the RSC model) was developed to allow for graphical presentation and analysis of this information. The program allows the user to choose a single project or a combination of projects to graph against the utility load curves for each island. If a combination of projects is chosen, the program sums the diurnal and or seasonal output from the different projects and graphs the combined output as a single line. This option allows the user to evaluate whether the combination of projects within an island provides a better load match than a single project.

Figures 4-1 to 4-3 are sample graphs from the utility load matching program for each technology on a diurnal and seasonal basis for the island of Hawaii. The basic shape of the utility load curve is similar on all the islands. Because there is a great number of possible graphing combinations, these graphs are provided as illustrative results only. This information provided the basis for conducting the capacity value and time-of-day analyses described below. In addition, a number of general conclusions can be drawn for each technology.

Figure 4-1 shows the diurnal and seasonal energy output patterns for a 30 MW solar thermal project at Waikoloa. The shape of the curves is similar for solar projects on each island regardless of the project size or solar technology utilized. As shown in the graphs, the shape of the seasonal curve follows the utility load curve fairly well. On a diurnal basis, however, the energy output from solar projects drops off before the utility system hits its daily peak load.

Figure 4-2 shows the diurnal and seasonal energy output patterns for a 30 MW wave energy project off the north Kohala coast. Again, the shape of these curves is similar for wave projects in other locations. Note, however, that high-quality wave resource data were not available to use as a basis for energy output estimates. Actual data from specific project sites may yield different results. As shown

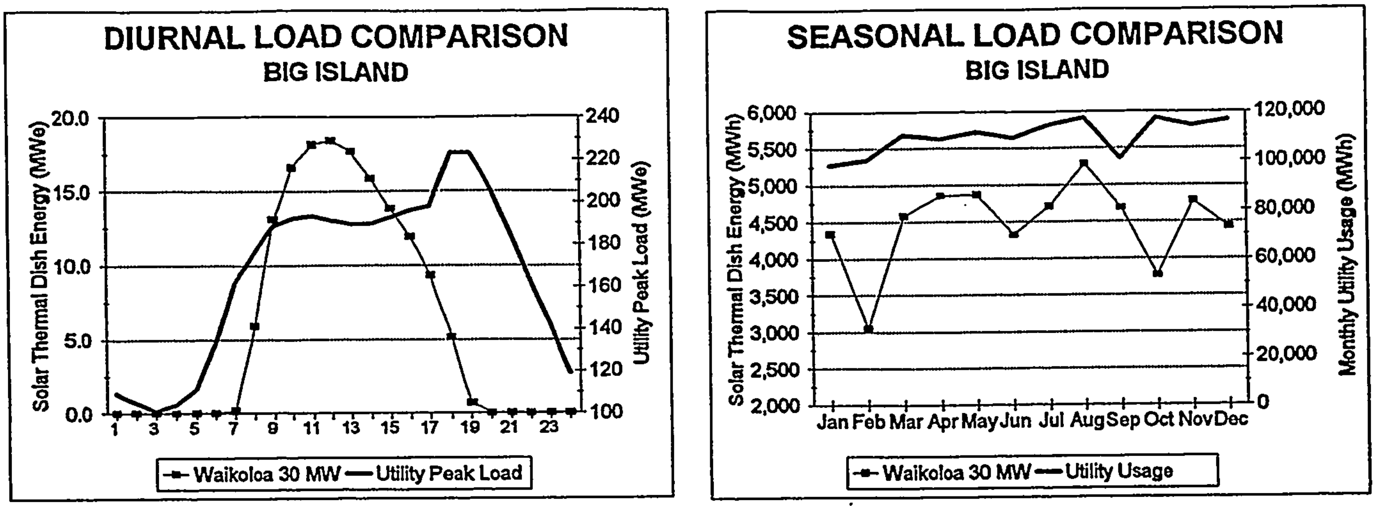


Figure 4-1. Diurnal and Seasonal Load Comparison, Solar

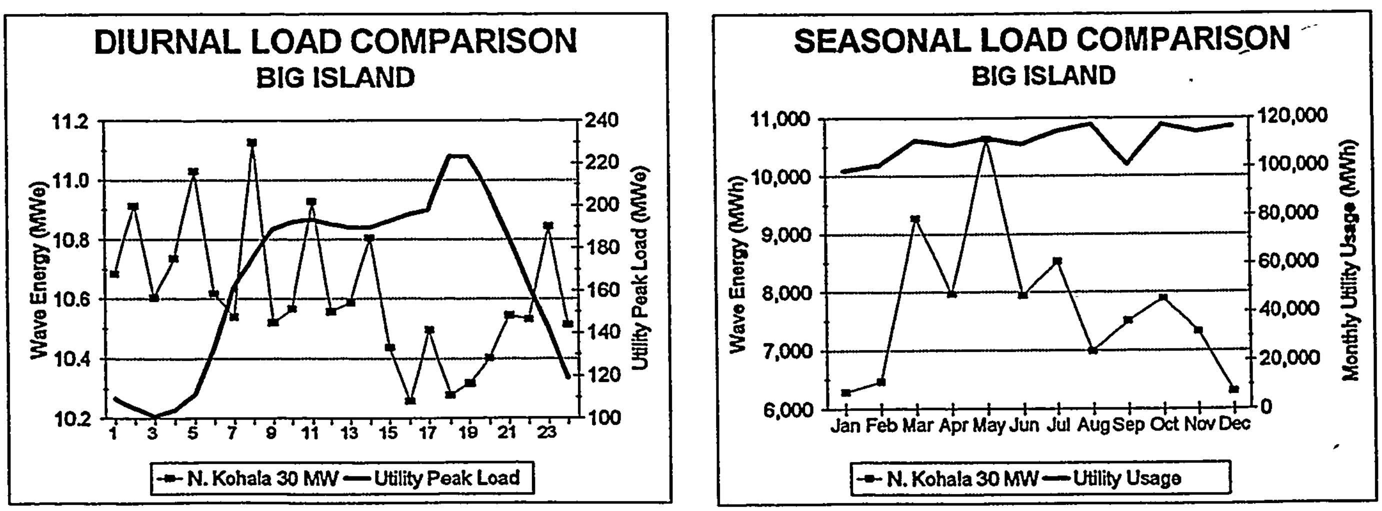


Figure 4-2. Diurnal and Seasonal Load Comparison, Wave

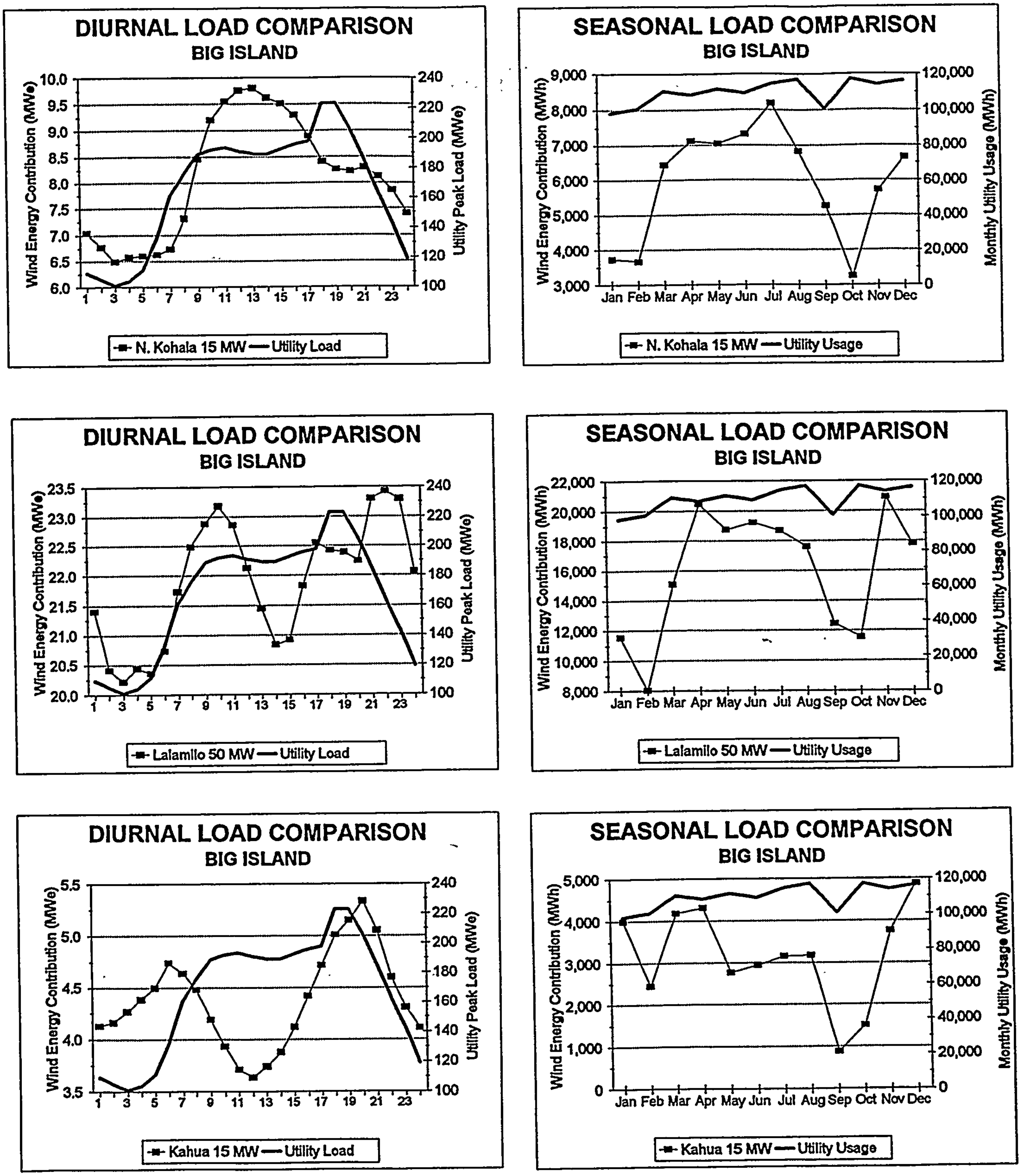


Figure 4-3. Diurnal and Seasonal Load Comparison, Wind

in the graphs, the shape of seasonal curve is not as well matched to the utility load as the solar curve. On a diurnal basis, the output from a wave project is variable and the shape of the curve is not particularly well matched to the utility load.

Figure 4-3 shows the diurnal and seasonal energy output patterns for three wind energy projects in different locations. Three graphs are shown to illustrate that the wind resource exhibits different seasonal and diurnal patterns in different project locations. In this example, the three sites – North Kohala, Lalamilo, and Kahua Ranch – are fairly close to each other. As shown in the graphs, the shape of the seasonal curves follows the utility load fairly well despite slight variations between projects. On a diurnal basis, the output of the three projects is significantly different. The North Kohala project exhibits the best match to the utility diurnal load; however, the Kahua Ranch project peaks at the same time as the utility system diurnal peak. Wind projects on other islands exhibit different diurnal patterns.

Because diurnal patterns can vary by season, diurnal estimates were developed for each month as well as on an annual basis. Figure 4-4 shows an example of how the diurnal pattern can vary by month at a typical wind project. Diurnal and seasonal outputs were not summarized for either biomass or ocean thermal projects because these project types are firm generating resources. It is possible to stockpile biomass fuel to generate energy only during periods of higher demand; however, this scenario would only be worthwhile if an economic incentive such as time-of-day payment rates was available.

CAPACITY VALUE FOR INTERMITTENT RESOURCES

Electrical generating plants are generally characterized by both an energy value and a capacity value. For intermittent resources, characterizing the *energy* value to a utility is relatively straightforward and generally represents the savings due to fuel displacement and possibly O&M cost. The *capacity* value of intermittent resources, however, is more difficult to quantify.

In the context of electric utility planning, capacity value refers to the ability of a generating resource to help meet peak loads. The capacity value depends on the quality and characteristics of the intermittent resource and on how well it complements the utility system under consideration. Capacity has value only if the addition of the resource to the system measurably increases the reliability of the system by reducing the probability that the system will fail to meet its peak loads. Practical experience with utilities in other locations (particularly with wind energy facilities) indicates that, in some cases, intermittent resources are able to defer the acquisition of other generating resources. Capacity value is extremely site-specific, however, and must be analyzed on a case-by-case basis.

Although there are little actual data available, some studies have suggested that the average capacity factor may be a reasonable indicator of wind energy capacity at low penetrations levels. In certain situations, however, this simplistic approach may result in an overestimation of capacity value. More sophisticated methods employed by utilities include conducting loss-of-load probability (LOLP) calculations as the basis for estimating capacity. A LOLP analysis requires detailed information about the capacity and forced outage rates of each unit in the utility system as well as detailed information about the intermittent generation output and the system load. A base case analysis is run using current loads and resources, then the new resource under consideration is added to the system (for intermittent technologies, it is generally modeled with a high forced outage rate), and the LOLP for both analyses is compared to a reference value. An LOLP analysis requires significant effort and very detailed operating information and was therefore beyond the scope of this study.

An intermediate approach to determining capacity value is to analyze the periods during which system loads are high and system marginal costs are likely to be correspondingly high. The underlying assumption with this approach is that capacity is acquired for its load carrying capability during periods of high loads. To analyze the capacity value of intermittent renewable energy projects in Hawaii, RLA examined the output from projects during periods of high hourly system loads. To conduct the analysis, the hourly system load values for the peak week in each month were summarized

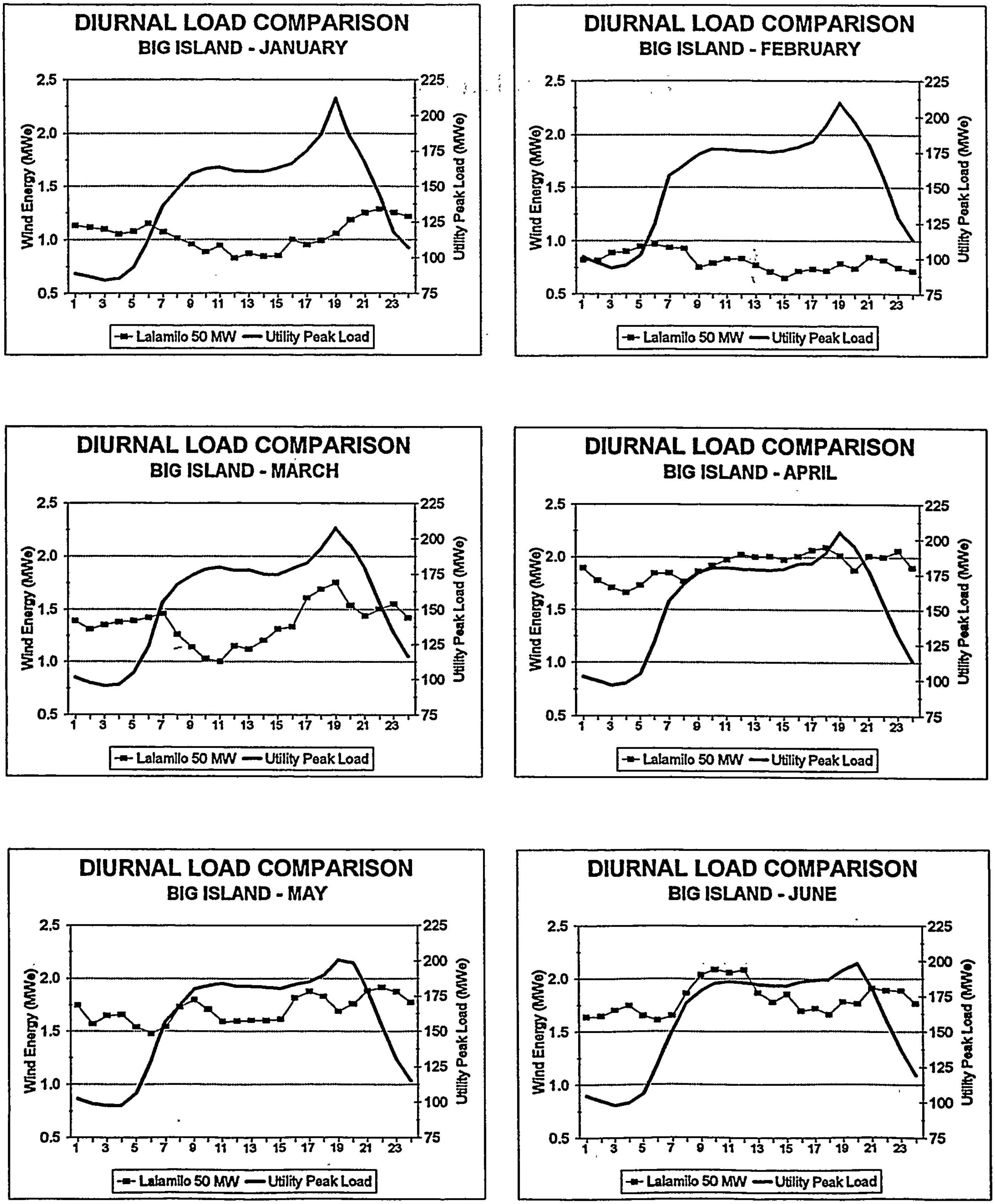


Figure 4-4. Monthly Diurnal Patterns, Wind

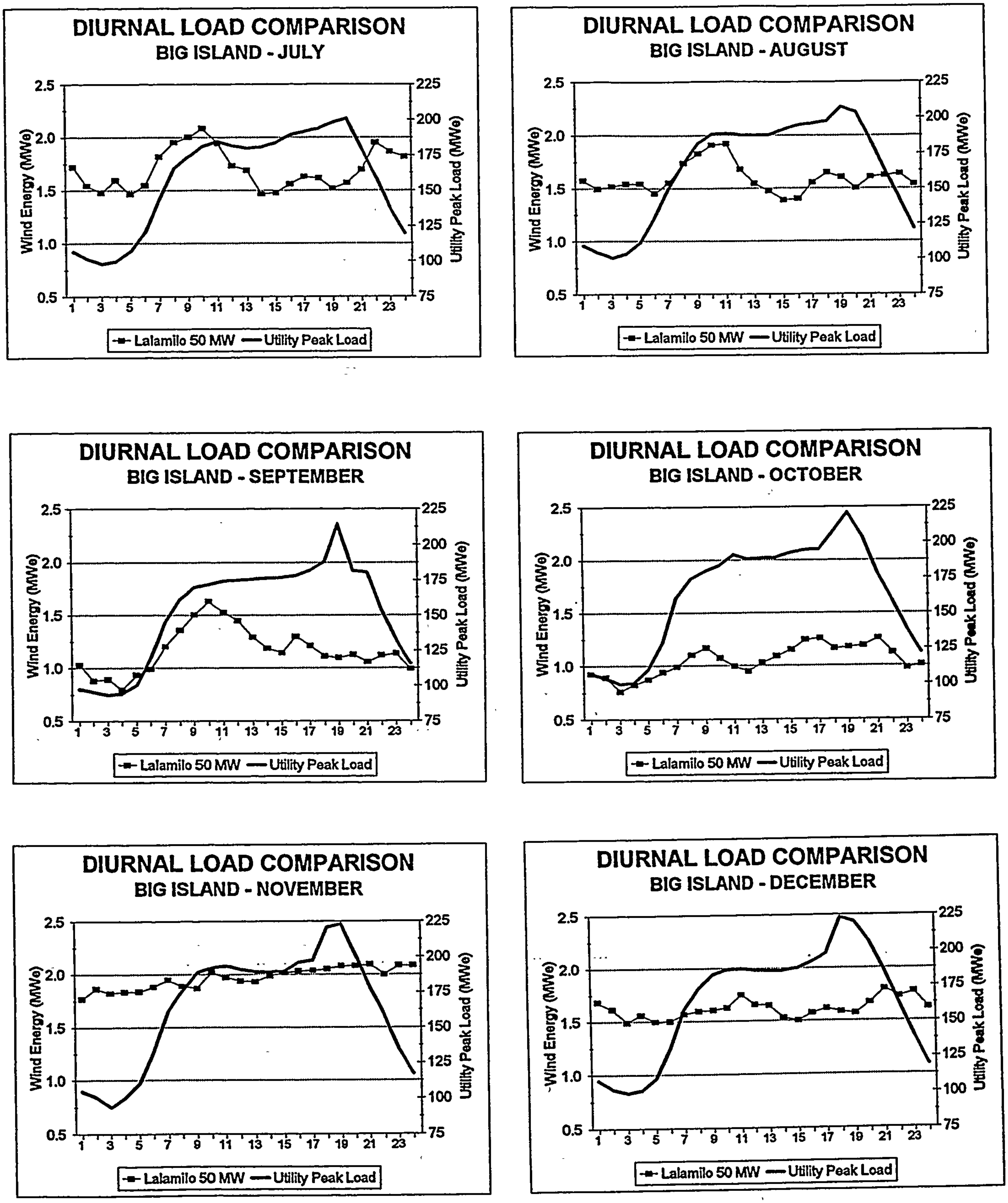


Figure 4-4. Monthly Diurnal Patterns, Wind (Continued)

for each utility in Hawaii. The hourly output which corresponded to the peak system values was then calculated for each intermittent renewable energy project (based on actual resource data). The results of this analysis for a typical wind, solar, and wave energy project are summarized graphically in Figures 4-5 to 4-7. In the graphs, the peak load hours and corresponding renewable energy project output are sorted in descending order and graphed as two separate lines. The renewable energy project output is given as a percent of its rated capacity. The variability of the intermittent resources during the high-load periods is easily seen on the graphs.

As shown in Figure 4-5, a typical wind energy project produces between 10% and 50% of its rated capacity during the peak hours of the year. This result can be interpreted to indicate that, at a minimum, wind energy projects provide a 10% capacity value to the utility. If the average rated capacity during peak hours is used to estimate capacity value, the project shown in Figure 4-5 would have a capacity value of approximately 25%. As shown on Figure 4-6, a typical solar project produces between 0% and 70% of its rated capacity during peak hours. The 0% values occur during the early evening peaks when the solar resource is unavailable. As shown in Figure 4-7, a typical wave project produces between 30% and 60% of its rated capacity during peak hours. If capacity value is determined based on a project's minimum rated capacity during peak hours, wave projects have the greatest capacity value to a utility.

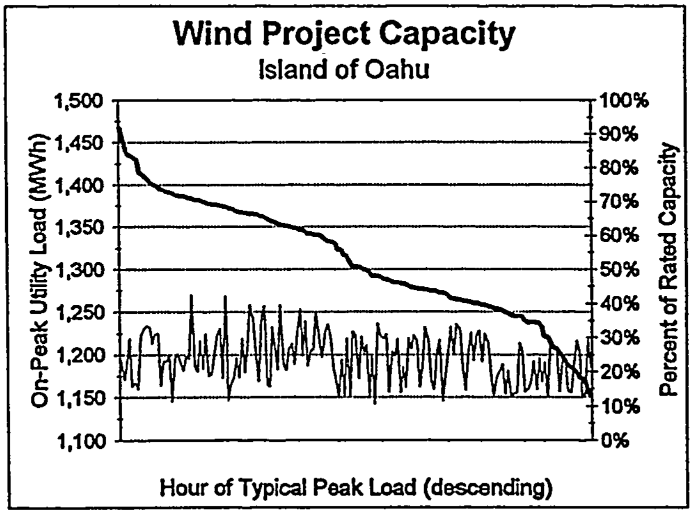


Figure 4-5. Peak Load versus Rated Capacity, Wind

Tables 4-1 to 4-4 show minimum and average capacity values for representative wind, solar, and wave projects on each island. The values are presented on both a monthly and annual basis. Because the wind projects exhibit varying diurnal patterns depending on the site, results for multiple wind energy projects are provided. The solar and wave energy diurnal patterns are similar between sites so only a representative project is shown.

Based on this analysis, there is evidence that wind and wave projects provide capacity value to a utility if minimum rated capacity during peak hours is used as the basis for estimating capacity value. On this basis, solar projects do not have a capacity value. If the average rated capacity during peak hours is used as the basis for estimating capacity value, solar projects have a fairly high capacity value (approximately 25%). This result indicates that although the output from a solar project is not

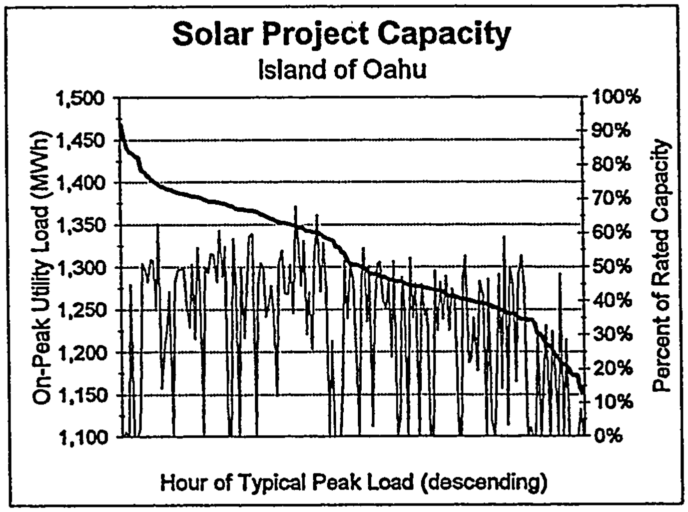


Figure 4-6. Peak Load versus Rated Capacity, Solar

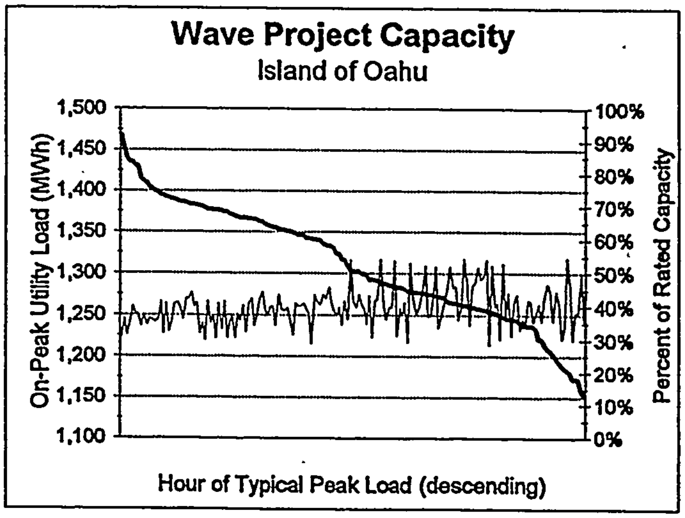


Figure 4-7. Peak Load versus Rated Capacity, Wave

available during the entire peak period, a high percentage of its rated capacity is available during the hours in which it is producing. The range of values for both analyses is fairly broad on a monthly basis as well as between projects. This illustrates the need to evaluate capacity value on a site-specific basis.

TIME-OF-DAY DELIVERY AND PRICING

To evaluate the impact that time-of-day delivery and pricing would have on potential renewable energy project implementation, a comparison of potential project revenues was made under different time-of-day energy delivery and payment scenarios.

Table 4-1. Percent of Capacity During On-Peak Hours, Island of Hawaii

Minimum Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Kahua Ranch	Lalamilo	N. Kohala	N. Kohala	N. Kohala
Jan	31.2%	27.6%	27.5%	0.0%	25.2%
Feb	18.5%	21.6%	28.6%	0.0%	30.5%
Mar	27.3%	33.4%	46.3%	0.0%	38.4%
Apr	29.0%	59.0%	49.8%	0.0%	34.7%
May	17.6%	51.4%	42.3%	0.0%	45.5%
Jun	21.1%	54.9%	47.7%	0.0%	35.2%
Jul	24.6%	48.9%	58.2%	0.0%	35.4%
Aug	25.6%	46.2%	48.1%	0.0%	27.8%
Sep	5.4%	35.3%	33.2%	0.0%	31.4%
Oct	11.4%	31.7%	23.7%	0.0%	33.3%
Nov	28.6%	62.3%	40.4%	0.0%	29.3%
Dec	36.3%	50.1%	53.5%	0.0%	25.6%
Avg	23.0%	43.5%	41.6%	0.0%	32.7%
Max	36.3%	62.3%	58.2%	0.0%	45.5%
Min	5.4%	21.6%	23.7%	0.0%	25.2%

Average Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Kahua Ranch	Lalamilo	N. Kohala	N. Kohala	N. Kohala
Jan	35.3%	32.7%	32.9%	42.4%	28.4%
Feb	23.8%	26.1%	34.4%	32.1%	32.2%
Mar	36.1%	44.5%	56.9%	41.3%	41.2%
Apr	41.2%	65.4%	66.6%	36.5%	36.5%
May	23.9%	57.0%	66.7%	39.2%	46.9%
Jun	29.0%	61.7%	68.5%	32.7%	36.4%
Jul	28.3%	57.2%	73.4%	25.5%	37.5%
Aug	30.3%	54.1%	64.3%	36.3%	31.0%
Sep	9.7%	42.6%	54.1%	48.4%	34.5%
Oct	13.9%	37.4%	30.4%	33.2%	35.6%
Nov	36.8%	66.5%	52.5%	30.4%	33.7%
Dec	42.6%	53.9%	56.9%	35.8%	28.2%
Avg	29.2%	49.9%	54.8%	36.2%	35.2%
Max	42.6%	66.5%	73.4%	48.4%	46.9%
Min	9.7%	26.1%	30.4%	25.5%	28.2%

Table 4-2. Percent of Capacity During On-Peak Hours, Island of Maui

Minimum Diurnal Percent of Capacity During On-Peak Hours

	Wind				Solar Thermal	Wave	
	McGregor Point	NW Haleakala	Puunene	West Maui	Kihei	Opana Point	Waiehu Pt.
Jan	8.5%	6.7%	11.5%	3.5%	0.0%	28.7%	27.4%
Feb	8.7%	6.9%	6.3%	16.0%	0.0%	34.7%	33.2%
Mar	20.9%	18.1%	22.5%	10.2%	0.0%	43.7%	41.8%
Apr	19.8%	16.6%	12.0%	8.4%	0.0%	39.5%	37.8%
May	13.5%	11.0%	3.2%	5.9%	0.0%	51.8%	49.5%
Jun	14.2%	11.1%	9.3%	14.9%	0.0%	40.1%	38.3%
Jul	21.6%	17.4%	8.0%	24.3%	0.0%	40.3%	38.5%
Aug	19.0%	15.6%	2.4%	30.6%	0.0%	31.6%	30.2%
Sep	7.7%	6.2%	0.0%	7.6%	0.0%	35.7%	34.1%
Oct	7.2%	5.9%	0.7%	7.9%	0.0%	37.9%	36.2%
Nov	8.3%	6.5%	5.3%	13.6%	0.0%	33.4%	31.9%
Dec	19.5%	16.5%	18.9%	14.0%	0.0%	29.1%	27.8%
Avg	14.1%	11.5%	8.3%	13.1%	0.0%	37.2%	35.6%
Max	21.6%	18.1%	22.5%	30.6%	0.0%	51.8%	49.5%
Min	7.2%	5.9%	0.0%	3.5%	0.0%	28.7%	27.4%

Average Diurnal Percent of Capacity During On-Peak Hours

	Wind				Solar Thermal	Wave	
	McGregor Point	NW Haleakala	Puunene	West Maui	Kihei	Opana Point	Waiehu Pt.
Jan	13.7%	11.4%	18.3%	8.3%	30.8%	32.3%	30.9%
Feb	20.3%	17.4%	10.5%	19.1%	25.6%	36.6%	35.0%
Mar	33.7%	29.6%	33.9%	15.3%	26.9%	46.9%	44.8%
Apr	42.5%	37.2%	28.8%	13.9%	33.5%	41.6%	39.7%
May	45.5%	39.9%	21.5%	10.3%	33.9%	53.4%	51.0%
Jun	49.8%	43.8%	29.9%	21.7%	33.0%	41.5%	39.6%
Jul	52.7%	46.7%	30.6%	29.2%	29.5%	42.7%	40.8%
Aug	48.7%	42.7%	22.9%	34.7%	31.0%	35.3%	33.7%
Sep	36.7%	31.7%	34.1%	16.4%	34.1%	39.3%	37.5%
Oct	33.4%	29.1%	10.9%	11.9%	26.0%	40.6%	38.7%
Nov	26.0%	22.2%	24.3%	17.1%	35.3%	38.4%	36.7%
Dec	29.3%	25.1%	27.1%	23.1%	31.2%	32.2%	30.7%
Avg	36.0%	31.4%	24.4%	18.4%	30.9%	40.1%	38.3%
Max	52.7%	46.7%	34.1%	34.7%	35.3%	53.4%	51.0%
Min	13.7%	11.4%	10.5%	8.3%	25.6%	32.2%	30.7%

Table 4-3. Percent of Capacity During On-Peak Hours, Island of Oahu

Minimum Diurnal Percent of Capacity During On-Peak Hours

	Wind		Solar Thermal	Wave	
	Kaena Point	Kahuku	Lualualei	Kahuku Pt.	Makapu Pt.
Jan	16.7%	10.7%	0.0%	28.6%	26.5%
Feb	7.9%	10.1%	0.0%	34.6%	32.1%
Mar	35.4%	27.9%	0.0%	43.6%	40.4%
Apr	22.6%	20.7%	0.0%	39.4%	36.6%
May	7.0%	17.8%	0.0%	51.7%	47.9%
Jun	12.6%	17.6%	0.0%	39.9%	37.1%
Jul	11.3%	24.4%	0.0%	40.2%	37.3%
Aug	8.8%	18.2%	0.0%	31.5%	29.2%
Sep	5.7%	11.7%	0.0%	35.6%	33.0%
Oct	6.6%	13.0%	0.0%	37.8%	35.1%
Nov	21.1%	12.6%	0.0%	33.3%	30.9%
Dec	16.9%	21.5%	0.0%	29.0%	26.9%
Avg	14.4%	17.2%	0.0%	37.1%	34.4%
Max	35.4%	27.9%	0.0%	51.7%	47.9%
Min	5.7%	10.1%	0.0%	28.6%	26.5%

Average Diurnal Percent of Capacity During On-Peak Hours

	Wind		Solar Thermal	Wave	
	Kaena Point	Kahuku	Lualualei	Kahuku Pt.	Makapu Pt.
Jan	25.0%	13.0%	27.5%	32.2%	29.9%
Feb	12.9%	13.9%	25.0%	36.5%	33.9%
Mar	42.5%	30.7%	27.8%	46.8%	43.4%
Apr	36.7%	25.6%	30.0%	41.4%	38.4%
May	24.2%	24.7%	29.1%	53.2%	49.4%
Jun	28.4%	28.8%	40.9%	41.3%	38.3%
Jul	31.8%	34.0%	35.2%	42.6%	39.5%
Aug	27.7%	26.6%	34.7%	35.2%	32.7%
Sep	17.3%	20.4%	28.3%	39.1%	36.3%
Oct	13.8%	19.9%	21.5%	40.4%	37.5%
Nov	35.5%	17.8%	30.2%	38.3%	35.5%
Dec	26.5%	26.4%	24.3%	32.1%	29.7%
Avg	26.9%	23.5%	29.6%	39.9%	37.0%
Max	42.5%	34.0%	40.9%	53.2%	49.4%
Min	12.9%	13.0%	21.5%	32.1%	29.7%

Table 4-4. Percent of Capacity During On-Peak Hours, Island of Kauai

Minimum Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Anahola	N. Hanapepe	Port Allen	Barking Sands	Barking Sands
Jan	12.5%	11.9%	5.1%	0.0%	14.0%
Feb	6.1%	10.6%	11.4%	0.0%	17.0%
Mar	23.7%	25.8%	3.0%	0.0%	21.4%
Apr	12.5%	22.7%	2.8%	0.0%	19.3%
May	7.5%	19.9%	3.8%	0.0%	25.3%
Jun	7.4%	22.4%	11.6%	0.0%	19.6%
Jul	6.8%	26.4%	11.3%	0.0%	19.7%
Aug	5.7%	24.6%	19.1%	0.0%	15.5%
Sep	4.5%	13.3%	9.5%	0.0%	17.5%
Oct	11.3%	18.2%	10.2%	0.0%	18.5%
Nov	19.4%	23.9%	10.5%	0.0%	16.3%
Dec	12.6%	24.7%	23.6%	0.0%	14.2%
Avg	10.8%	20.4%	10.2%	0.0%	18.2%
Max	23.7%	26.4%	23.6%	0.0%	25.3%
Min	4.5%	10.6%	2.8%	0.0%	14.0%

Average Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Anahola	N. Hanapepe	Port Allen	Barking Sands	Barking Sands
Jan	15.1%	16.1%	18.7%	30.5%	15.8%
Feb	8.6%	15.9%	22.1%	24.4%	17.9%
Mar	26.2%	29.3%	27.1%	30.5%	22.9%
Apr	16.9%	27.5%	17.1%	32.7%	20.3%
May	11.2%	26.4%	16.1%	32.8%	26.1%
Jun	11.1%	29.5%	47.2%	34.9%	20.3%
Jul	9.9%	34.5%	40.8%	31.7%	20.9%
Aug	9.5%	28.9%	54.9%	32.1%	17.3%
Sep	7.9%	18.5%	23.6%	43.1%	19.2%
Oct	14.7%	22.1%	14.9%	30.9%	19.8%
Nov	25.9%	29.0%	27.4%	30.9%	18.8%
Dec	14.5%	29.1%	33.2%	22.5%	15.7%
Avg	14.3%	25.6%	28.6%	31.4%	19.6%
Max	26.2%	34.5%	54.9%	43.1%	26.1%
Min	7.9%	15.9%	14.9%	22.5%	15.7%

Table 4-5 contains a summary of the analysis results for each technology type on the island of Hawaii. The results are similar on each island. The table includes one representative project for each intermittent resource technology. Multiple wind projects are included because their diurnal patterns vary and the results vary by project site.

As shown in the table, potential revenues from electricity sales were calculated for each project based on average avoided cost payments and on an assumed time-of-day payment scheme. The time of day payment rates are based on 1993 on-peak and off-peak avoided costs provided by the Hawaiian utilities projected to the year 2005 using a 5% escalation rate. The nature of the results of this analysis are not sensitive to the chosen rate of escalation. Under current practice, the avoided cost payment rate is averaged according to the number of on-peak and off-peak hours experienced by the utility regardless of the timing of energy delivery.

As shown in the table, time-of-day pricing makes a significant difference for the solar technologies. The potential revenues are increased by approximately 7%. This result is consistent with the diurnal energy delivery patterns from a solar project, which illustrates that all the energy is delivered during peak load periods. For wave projects, time-of-day pricing actually decreases the potential revenue from projects. This result illustrates the lack of match with the diurnal utility demand curve. The potential revenues from wind energy projects increases with time-of-day pricing; however, the extent of the increase is fairly small (1%-2%). Time-of-day pricing analysis results from all the intermittent projects on each island are included in Appendix E.

Table 4-5. Energy Payment Comparison, Island of Hawaii

			Project	Payment - 2005		Daily	Annual Sales		Time of Day
			Capacity	Average	Time of Day	Energy	Based on	Based on	Pricing
Technology	Type	Location	(MW)	($/kWh)	($/kWh)	(MWh)	Average	Time of Day	Advantage
Photovoltaic	tracking	Keahole	50	$0.0906	$0.0972	376.5	$12,451,070	$13,355,167	$904,096
Solar Thermal	dish	Waikoloa	30	$0.0906	$0.0973	146.9	$4,857,058	$5,217,107	$360,050
Wave		Honokaa 2A	10	$0.0906	$0.0905	92.0	$3,043,067	$3,041,298	($1,769)
Wave		N. Kohala	30	$0.0906	$0.0905	254.8	$8,427,373	$8,422,474	($4,900)
Wind		Kahua Ranch	15	$0.0906	$0.0906	105.2	$3,478,068	$3,478,090	$22
Wind		Lalamilo Wells	50	$0.0906	$0.0908	525.5	$17,379,153	$17,408,101	$28,948
Wind		N. Kohala	15	$0.0906	$0.0915	194.8	$6,440,754	$6,505,343	$64,589

SECTION 5. RENEWABLE ENERGY IMPLEMENTATION PLAN

As discussed in Sections 2 and 3, the set of projects that were identified as viable in the 1995 and 2005 analyses are viable only as individual projects, not as a group. There are a number of additional factors which impact project implementation that are not considered in the resource supply curve analyses. This section provides an overview of factors that impact the development and implementation of renewable energy projects and presents a plans for integrating renewable energy projects into the state's generation mix by island.

The RSC program ranks projects based on the lowest cost of energy. The projects presented in the previous sections are, in actuality, unlikely to be developed in this order. Although cost effectiveness is certainly one of the primary considerations, other factors will more likely determine the actual development sequence as well as the appropriate project size to be developed. These factors range from subjective considerations, such as the interest of the land owner in leasing the land for a renewable energy project, to more quantifiable considerations, such as the limits imposed on project development due to the energy demand growth rate. Phase 1 of this program included a detailed screening process to eliminate projects with obvious barriers to development and resulted in a list of projects that appear to be technically feasible. Phase 2 provided information on the economic feasibility of these projects. Phase 3 consisted of integrating this information and including consideration of other practical factors that impact the project development to arrive at an implementation plan.

CONSTRAINTS TO RENEWABLE ENERGY PROJECT IMPLEMENTATION

Hawaii has an abundance of renewable energy resources. For most renewable energy technologies, a sufficient resource exists on each island to warrant consideration of an energy project. There are a number of constraints to renewable energy project implementation, however, that are unique to the State of Hawaii. For example, one of the largest factors in eliminating potential projects from consideration in Phase 1 was the availability of land without conflicting or potentially competing land uses. Only on the island of Hawaii and on the lightly populated islands of Lanai and Molokai were sites identified in which the potential for competing land uses were not considered to be an issue. This is not to say that development of projects is impossible on the other islands; only that the demand for land is high and the impact of an energy project on a particular site will be weighed against other potential uses for that land as well as any potential impacts on activities on surrounding lands.

The total generating capacity of the utility grid and the projected demand growth on each island provides the greatest limitation to renewable energy project implementation in the next ten years. Of course, it is possible that renewable energy projects could replace existing fossil fuel plants; however, because the investment in these units has already been committed, this is not expected to be an economical alternative unless fuel prices rise to unprecedented levels, or if some of these fossil fuel plants are retired earlier than expected..

The relatively small size of the utility grids also limits renewable energy potential development, particularly of intermittent generating technologies. Although a number of studies have indicated that penetration limits of intermittent generating resources can meet or exceed 20% of the peak demand without operating penalties, results of such analyses are extremely variable and require detailed load flow and system stability analyses based on specific grid conditions to ensure utility reliability is achieved under all operating conditions. While such detailed utility analyses are beyond the scope of this study, the wealth of potential renewable energy project development opportunities identified by this work should serve to encourage these activities by utilities and other interested parties.

Public acceptance is another constraint to development that is difficult to quantify. Public opinion surveys show a clear preference for renewable energy projects over conventional generation technologies; however, the vast majority of all development projects are subject to some type of public opposition.

DEVELOPMENT OF RENEWABLE ENERGY PROJECT IMPLEMENTATION PLAN

The renewable energy projects that are viable under the set of assumptions presented have been summarized and prioritized in terms of which technologies and project sites hold the greatest promise for assimilation into each island's electrical grid. Renewable energy integration plans were developed based on the 2005 resource supply curve results and consideration of the constraints to implementing renewable energy projects that are discussed above. In developing the renewable energy integration plan, the following process was considered.

The primary consideration for a renewable energy integration plan is the projected load growth on each island. Table 5-1 summarizes the peak load and estimated electricity sales for 1995 and 2005 for each island. As shown in the table, the amount of renewable energy that can be integrated into each utility in the next ten years is bounded by the projected load growth. Note that existing units could be retired or replaced by renewable energy projects if this appeared to be economically feasible; however, that would be the subject of a different analysis.

Table 5-1. Peak Load and Estimated Electricity Sales

	Hawaii	Maui	Oahu	Kauai
2005 Peak Load (MW)	223.0	229.5	1,467.2	84.6
Estimated Energy Sales - 1995	957,013	880,956	6,950,000	398,699
Estimated Energy Sales - 2005	1,416,614	1,042,711	8,550,887	568,304
Growth (MWh)	459,601	161,755	1,600,887	169,605
Maximum Intermittent (20%)	44.6	45.9	293.4	16.9

The penetration limit for intermittent renewable resources is another major consideration in determining the appropriate renewable energy project mix. Previously conducted, generalized studies in Hawaii have indicated that a practical cumulative intermittent resource penetration limit on each of the isolated island utility systems can be estimated at 10% of the annual peak load without operating penalties. As previously discussed, more detailed studies are required to determine appropriate levels above this estimate and given the large number of economically viable, intermittent renewable energy projects, such studies are immediately warranted. It is anticipated that such studies will permit higher penetration limits on each island, particularly given the likelihood of more efficient utility operating practice by 2005, expected technological improvements in the generating equipment, and the availability of more detailed energy production estimates for the proposed projects. As a result of these considerations, a penetration limit of 20% of peak load was assumed for the purposes of developing an integration plan. These values are also provided for each utility in Table 5-1.

The value of 20% as a maximum penetration limit was chosen in anticipation of likely results from more detailed studies of the power system of each island. It should be noted that intermittent renewable energy projects such as wind and run-of-river hydro may not produce at their rated capacity at any given time. Combinations of intermittent renewable energy projects in any system are even less likely to produce at their combined rated capacity. By considering such combined effects, or possible other operating strategies, detailed studies may even allow levels of intermittent renewable energy development higher than 20%.

The relative cost of energy for the renewable projects was the next major consideration in determining the appropriate renewable energy plan on each island. The projects that appeared to be economically viable under the conservative scenarios were considered first. The most economic project size (generally the largest) was included if the assumed penetration limits (for intermittent technologies) and/or the load growth limits had not yet been exceeded. Nominal scenarios and then optimistic scenarios were then evaluated to determine the additional projects sites, technologies, and project sizes that were appropriate to consider in the analysis.

Prioritized projects are summarized for each of the islands in the following sections. In all cases, the integration plans include intermittent projects totaling less than 20% of the annual peak load. Even with this limitation, it appears feasible to meet all new generating requirements in the next ten years with renewable energy additions. This is a valid objective for the State of Hawaii to consider.

The recommended integration plan provided for each island represents realistic goals that can be easily achieved if reducing the oil dependency is a priority for both the government and the utilities. Should conditions occur such as changes in the operating characteristics of the utilities, incorporation of energy storage, widespread use of electric vehicles, or island interconnection, significantly more renewable energy could be incorporated into the generation mix. As a result, the projects listed in the previous sections are all considered viable options for the future, even if they are not discussed in the integration plans.

ISLAND OF HAWAII

Table 5-2 presents the recommended renewable energy integration plan for the island of Hawaii. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Hawaii. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Table 5-2. Renewable Energy Integration Plan, Island of Hawaii

2005 PEAK LOAD	223.0	MW
ESTIMATED ENERGY DEMAND INCREASE	459,601	MWH
20% OF PEAK LOAD*	44.6	MW

TECHNOLOGY	LOCATION	CAPACITY (MW)	ENERGY CONTRIBUTION (MWH)
WIND	N. KOHALA	15	71,178
WIND	LALAMILO	30	115,714
GEOTHERMAL	KILAUEA	50	362,314
HYDROELECTRIC	UMAUMA STREAM	13.8	40,199
TOTAL RENEWABLE ENERGY		108.8	589,405

*PENETRATION LIMIT FOR INTERMITTENT RESOURCES

NOTE: ENERGY CONTRIBUTION VALUES ARE BASED ON NOMINAL ENERGY PROJECTION ESTIMATES.

As previously discussed, the total capacity of intermittent technologies such as wind was restricted to 20% of the peak load for 2005. As a result, only 45 MW of wind energy projects are included in the plan. Additional wind energy development is possible if conditions are shown to allow a higher penetration. The North Kohala project was chosen because it is the most cost-effective wind energy project on the island. Inclusion of this project limits additional development at Lalamilo (the next most cost-effective project) to 30 MW in order to remain within the assumed penetration limits. Note that a larger project at Lalamilo is feasible as is a project at Kahua Ranch, should the North Kohala project be undevelopable for factors other than cost.

The hydroelectric project on Umauma Stream is the next project included in the plan. Implementation of this project may be hindered by public opposition; however, its energy contribution is relatively small and if it is not considered, the output from the remaining projects would still exceed the projected demand increase.

A geothermal project in the Kilauea East Rift Zone is also included in the plan. The 50 MW project size is included because it is more cost effective than the 25 MW size even though the annual energy production from this project results in a combined total far greater than the anticipated demand increase. In the event that further geothermal development on the island is not able to proceed in the desired time frame, a biomass project located on the Hilo Coast or other locations could meet the same need for firm generating capacity.

ISLAND OF MAUI

Table 5-3 presents the recommended renewable energy integration plan for the island of Maui. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Maui. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Table 5-3. Renewable Energy Integration Plan, Island of Maui

2005 PEAK LOAD	**229.5**	**MW**
ESTIMATED ENERGY DEMAND INCREASE	**161,755**	**MWH**
20% OF PEAK LOAD*	**45.9**	**MW**

TECHNOLOGY	LOCATION	CAPACITY (MW)	ENERGY CONTRIBUTION (MWH)
WIND	MCGREGOR POINT	10	24,611
BIOMASS - ORGANIC WASTE	PUUNENE	25	153,300
WIND	NW HALEAKALA	30	56,140
TOTAL RENEWABLE ENERGY		65	234,051

*PENETRATION LIMIT FOR INTERMITTENT RESOURCES

NOTE: ENERGY CONTRIBUTION VALUES ARE BASED ON NOMINAL ENERGY PROJECTION ESTIMATES.

Although there is some resource uncertainty at the site, a wind project at McGregor Point is the most cost-effective project on Maui. A wind project on the northwest slope of Haleakala is also included in the plan. Additional wind projects at other sites are also feasible and could replace these two if they should prove to be undevelopable for factors other than cost.

A biomass project using organic waste as the fuel source is also included in the plan. This project assumes that a revenue stream similar to tipping fees is available to the project. A biomass electric project using tree crops as the fuel source would be the next project to be included if the assumption about tipping fees proves to be inaccurate.

ISLAND OF OAHU

Table 5-4 presents the recommended renewable energy integration plan for the island of Oahu. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Oahu. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Table 5-4. Renewable Energy Integration Plan, Island of Oahu

2005 PEAK LOAD	1,467.2	MW
ESTIMATED ENERGY DEMAND INCREASE	1,600,887	MWH
20% OF PEAK LOAD *	293.4	MW

TECHNOLOGY	LOCATION	CAPACITY (MW)	ENERGY CONTRIBUTION (MWH)
BIOMASS-ORGANIC WASTE	BARBERS POINT	50	306,600
WIND	KAENA POINT	15	31,558
WIND	KAHUKU	80	151,558
SOLAR THERMAL - DISH	PEARL HARBOR	50	84,942
SOLAR THERMAL - DISH	LAULAULEI	50	80,912
PHOTOVOLTAIC - TRACKING	N. EWA PLAIN	50	111,675
BIOMASS - GRASS CROPS	WAIALUA	25	153,300
WAVE	MAKAPUU	60	224,378
WAVE	KAHUKU POINT	60	211,197
WAVE	NE COAST	60	205,535
TOTAL RENEWABLE ENERGY		500	1,609,130

*PENETRATION LIMIT FOR INTERMITTENT RESOURCES

NOTE: ENERGY CONTRIBUTION VALUES ARE BASED ON NOMINAL ENERGY PROJECTION ESTIMATES.

Because Oahu has a significantly higher energy demand than the other islands, a large number of projects are included in the integration plan. Unlike Hawaii and Maui, where there are a number of viable integration plan possibilities, the demand increase on Oahu requires consideration of the majority of projects that are considered to be viable under the optimistic scenarios. If only projects that were shown to be viable under nominal conditions were included in the plan, they would only be able to contribute 30% of the demand increase.

A biomass electric project using organic waste as the fuel source is the most economical project on Oahu. A waste-to-energy facility is already in operation on this island and this facility could be located in the same region to take advantage of existing transportation plans. Wind projects at Kaena Point and Kahuku are also included in the plan at their largest size. These three projects are viable even under nominal conditions.

Additional projects included in the plan include significant quantities of photovoltaics, solar thermal, biomass electric, and wave energy generation. Although these projects are all viable under optimistic assumptions, their development status is more uncertain. Due to their significant energy contribution potential, however, they should be seriously considered as future alternatives.

ISLAND OF KAUAI

Table 5-5 presents the recommended renewable energy integration plan for the island of Kauai. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Kauai. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Table 5-5. Renewable Energy Integration Plan, Island of Kauai

2005 PEAK LOAD	84.6	MW
ESTIMATED ENERGY DEMAND INCREASE	169,605	MWH
20% OF PEAK LOAD*	16.92	MW

TECHNOLOGY	LOCATION	CAPACITY (MW)	ENERGY CONTRIBUTION (MWH)
WIND	N. HANAPEPE	10	22,602
WIND	PORT ALLEN	5	9,321
HYDROELECTRIC	WAILUA RIVER	6.6	16,435
BIOMASS - TREE & ORGANIC WASTE	KAUMAKANI	25	153,300
SOLAR THERMAL - DISH	BARKING SANDS	10	17,250
TOTAL RENEWABLE ENERGY		56.6	218,908

*PENETRATION LIMIT FOR INTERMITTENT RESOURCES

NOTE: ENERGY CONTRIBUTION VALUES ARE BASED ON NOMINAL ENERGY PROJECTION ESTIMATES.

The integration plan for Kauai includes a wide variety of technology types. Wind projects are viable in two locations under conservative conditions. As with the hydroelectric project on Hawaii, this technology is subject to public opposition. It is included in the plan for its cost-effectiveness; however, its contribution is relatively small and if it is not considered, the output from the remaining projects would still exceed the projected demand increase.

The next most cost-effective project included in the database is a 50 MW biomass electric project at Kaumakani including both tree crops and organic waste as the fuel source. A 50 MW project is too large to be considered by 2005. As a result, a 25 MW project was included in the plan even though this project size was not included in the database. A 25 MW project using only tree crops as a fuel source was considered at Lihue and this project could also feasibly be included in the plan; however, the Lihue biomass project is less cost effective than a solar thermal project at Barking Sands under nominal conditions. As a result, the solar thermal projects and a smaller biomass project at Kaumakani were included in the plan.

OPPORTUNITIES FOR SMALL-SCALE RENEWABLE ENERGY PROJECT IMPLEMENTATION

Small-scale renewable energy projects are also well suited for the islands, particularly Lanai and Molokai, where limited demand restricts utility-scale development yet also results in high energy costs. Small-scale renewable energy projects, either through demand-side or dispersed-generation applications, should be economical on a widespread basis and have the potential to make a significant contribution to reducing petroleum dependency. Although small-scale projects are likely to be possible at many locations on each island, the larger projects described for the larger islands will make a more substantial contribution. Nonetheless, these opportunities should be pursued to the greatest extent possible.

The economics and market potential for small-scale renewable energy applications is difficult to quantify. The economics are dependent on the costs of alternative sources of supply which are extremely site specific. For isolated users, the economics are usually compared to the cost of grid extension. For grid-connected users, the economics are dependent on the cost of electricity and the power purchase terms available to sell any excess generation to the utility.

Promising applications for small-scale renewable energy projects that may be feasible for locations in Hawaii include dispersed generation, demand-side, off-grid, and grid support projects. These small-scale applications may be viable for both residential and commercial or industrial energy users. Although it was beyond the scope of this study to estimate the market potential for each of the applications, RLA developed representative project costs and performance estimates for a number of the most promising small-scale renewable energy applications on Hawaii. These "case studies," which include a description of the potential application, cost and performance summaries, and references for additional information, are included in Appendix F.

Other case studies presented illustrate promising applications for using the near shore cold water resource. Note that even in the 2005 optimistic case the levelized cost of energy for a closed cycle OTEC power plant at Keahole Point is 12.5 cents per kWh. Services available from open cycle desalination and deep seawater cooling can be more economically competitive than their conventional alternates (see Appendix F for details).

SECTION 6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Renewable energy projects can provide all the new generation required to meet projected energy demand increases between 1995 and 2005. On Maui, this can be accomplished with projects that are cost competitive even under the most conservative assumptions. On Hawaii and Kauai, this can be accomplished with projects that are cost competitive under nominal scenarios. If conservative assumptions are used, Hawaii and Kauai can still obtain 50% and 25% of the projected energy demand growth from renewable energy projects, respectively. On Oahu, under nominal assumptions, renewable energy projects can provide over 30% of the new generation required to meet energy demand increases and under optimistic conditions, all the energy required to meet energy demand increases.

Based on these results, it is a realistic goal for the State of Hawaii to add only renewable energy projects to meet future energy demand growth between 1995 and 2005 and even beyond. It is appropriate to begin working on this goal immediately because several projects are cost competitive now.

Under optimistic assumptions, enough energy could be produced from renewable energy projects to meet most, if not all, the electricity requirements on Maui, Hawaii, and Kauai. Constraints to project implementation, conventional generation units already in place, and projected demand growth make this result unrealistic. It does illustrate, however, that under optimistic circumstances, investments in conventional fossil fuel plants will turn out to be uneconomical in the future. This conclusion is supported by both the 1995 results that indicate that there are already substantial investments in renewable energy resources that are more economical than the avoided energy cost from fossil fuel technologies (the basis for avoided cost); and by the nominal case calculation presented for 2005.

At the other extreme, conservative scenarios provide a minimum number of projects that should be considered and implemented in the state. Because investors have experienced financial losses due to excessively optimistic assumptions for renewable energy projects in the past, they may be inclined to lean towards the conservative estimates. Nonetheless, a number of viable projects exist even under this scenario. These projects can be pursued with a high confidence level in their costs and conservative performance estimates and with a minimum amount of risk to the investor. If the projects identified as viable in 1995 and those that are viable in 2005 under conservative conditions are installed as soon as possible, the experience gained from these projects will help narrow the range of projected development cost estimates for other projects installed in the future.

The annual savings benefits shown in the tables in this report for the 2005 scenario may be unrealistic because they are based on a comparison with projected avoided energy cost. The magnitude of the benefit is not as important as the fact that there is indeed a benefit in implementing renewable energy projects over continuing with the current practice of relying heavily on fossil fuel. There are other benefits also which have not been included in the data presented. Employment benefits would flow to the residents of the state because construction and operation of renewable energy projects involve more labor than for comparatively sized fossil fuel plants. A greater use of Hawaiian resources also insulates the state from fuel price escalation. Furthermore, the obvious environmental advantages of using renewable energy have not been incorporated into the results.

RECOMMENDATIONS

Whether the projects are evaluated based on the optimistic, conservative, or nominal scenarios plays a big part in determining the pace of renewable energy development in Hawaii. Many renewable technologies have developed at a slower rate than historically projected. On the other hand, the extent of commercial wind energy development over the last ten years provides a good illustration of the speed in which renewable energy technologies can mature. This is in part driven by research and development funding levels and other policy choices. Although the nominal cases represent the most reasonable estimates, both the optimistic and conservative cases are possible scenarios – neither represents an unrealistic extreme.

Economic conditions unrelated to the pace of technology development will also be a major factor in determining the level of renewable energy integration in Hawaii. Avoided cost levels or power purchase contract terms will play a large role in determining the projects that are developed. Although the state cannot control the price of oil, it can influence the power purchase contract terms that are available to independent power producers. In addition to encouraging utilities to construct contracts with favorable terms for renewables, the state must also allow the costs associated with these contracts to be included in the utility's rate base. Factors that have been shown to be favorable to renewables include consideration of capacity value and time-of-day pricing. Contract structures that assist in obtaining financing at favorable rates (such as front loaded contracts and long-term contracts with specified payment schedules) will also promote renewable energy integration.

The state can also continue to support and encourage research and analysis that promote renewable energy implementation. Because a significant number of additional renewable energy projects could be developed if not for the penetration limits for intermittent technologies on isolated grids, studies addressing this issue should be a priority. Because such studies require a significant level of effort and detailed information about utility system characteristics, these analyses should be conducted in cooperation with the utilities.

Energy storage options, if economical, would also address the penetration limits issue. It is recommended that the costs and operation of promising energy storage possibilities be evaluated to determine if such technology is viable. An evaluation conducted with the same approach and economic methodology as the resource supply curve data would facilitate the evaluation.

For the projects that appear to be viable based on the results of this program, detailed feasibility studies can be performed to further refine their costs and performance. These activities may be carried out by a developer, utility, or government agencies interested in the project development.

Additional resource assessment and technological research would address the uncertainty in the estimates and reduce the range between conservative and optimistic estimates. Resource assessment should focus on areas in which insufficient data are available to accurately define performance. For example, wave energy projections are particularly broad and resource assessment activities would greatly reduce the performance uncertainty. Wave energy projects would also benefit from technological research. Wave projects had significant potential for Hawaii under the optimistic scenarios but were extremely costly under conservative assumptions. Demonstration projects or practical research geared toward commercial development could provide more confidence in the cost and performance of these technologies.

For wind projects, a number of viable projects already exist. On Hawaii and Maui, more electricity can be generated by wind projects than the utility can accept. On Oahu, large-scale projects have been identified and additional wind projects are unlikely because of land use constraints. As a result, additional resource assessment activities should be geared towards micrositing for the specific projects already identified or establishing long-term reference stations to support project development and operation. Because such limited wind resource data exist on Kauai, additional data collection to identify sites may be valuable. At a minimum, monitoring should continue at the promising sites.

Although wind projects could also benefit from research activities, achieving cost and performance improvements is not necessary to make these projects viable under even the most conservative assumptions. As a result, wind energy project integration will likely benefit more from policy initiatives such as facilitating the permitting requirements or establishing financeable power purchase contracts than they will from research.

A number of solar technology projects are close to being cost-effective under nominal conditions. Both solar thermal dish projects and photovoltaic tracking projects are close enough to being viable that they warrant serious consideration. Capacity credit, time-of-day pricing, or tax credit changes could result in these projects being viable generation options in the next ten years even under nominal or conservative conditions. Hawaii could assist in the development of these technologies by participating in demonstration projects or research activities. Hybrid systems that utilize gas, biomass, or other fuel in conjunction with solar thermal heat are receiving considerable attention and may hold promise for Hawaii applications. These systems can operate as firm generating resources. At a minimum, the technology improvements should be tracked and incorporated into planning processes. Solar thermal troughs do not appear to be viable options for development in Hawaii.

Biomass electric and biomass fuels are both promising technologies for Hawaii and their development and implementation should be pursued. In addition to offering the only firm renewable energy option that is economically viable, biomass plantations allow the state to preserve a portion of its land in agricultural crops which provides valuable benefits to the state's residents as well as promotes the tourist industry. Although biomass fuels were not the primary focus of this study, results indicate that the costs are in the general range of expected market prices for fuel alternatives. Biomass fuels offer the additional benefit of being transportable.

Hydroelectric and geothermal projects are commercially viable in Hawaii today; however, a limited number of developable sites exist. Their development is also subject to significant public opposition. Additional resource assessment or research is unlikely to change the analysis results. The projects identified in this study should be pursued to the extent in which they are viewed as acceptable to the public.

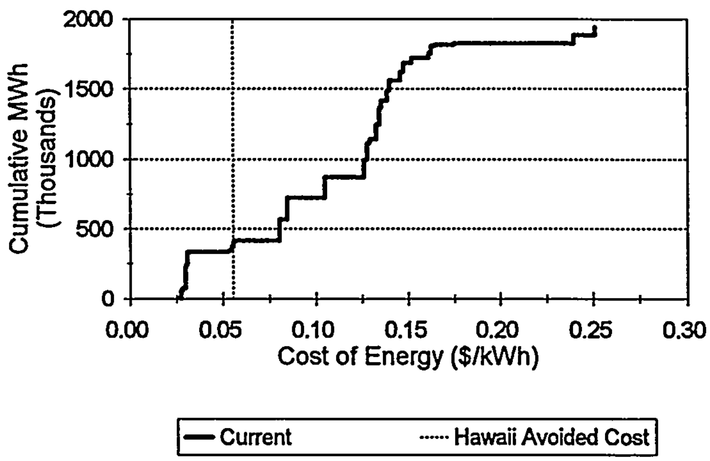
Although only two ocean thermal projects were evaluated in this project, neither was shown to be cost effective even in the most optimistic case. Although ocean thermal technology may offer a significant contribution to Hawaii's generation mix in the long-term, it does not appear at this time that it will be competitive with other renewable energy options in the next ten years.

APPENDIX A

RESOURCE SUPPLY CURVES, ISLAND OF HAWAII

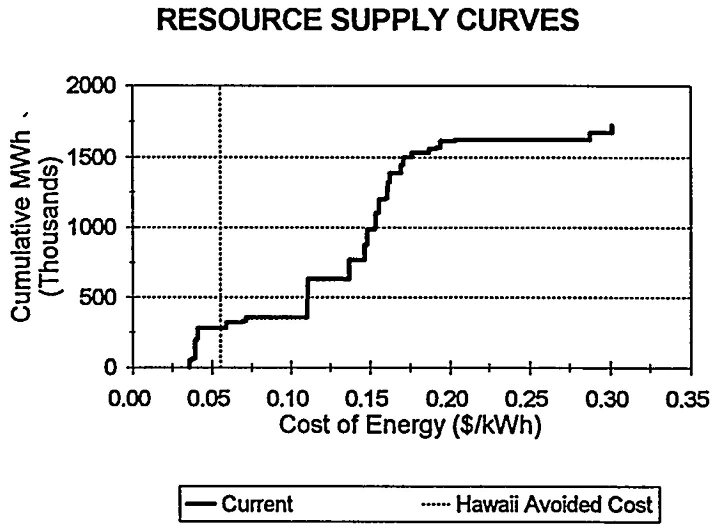
Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0556

RESOURCE SUPPLY CURVES



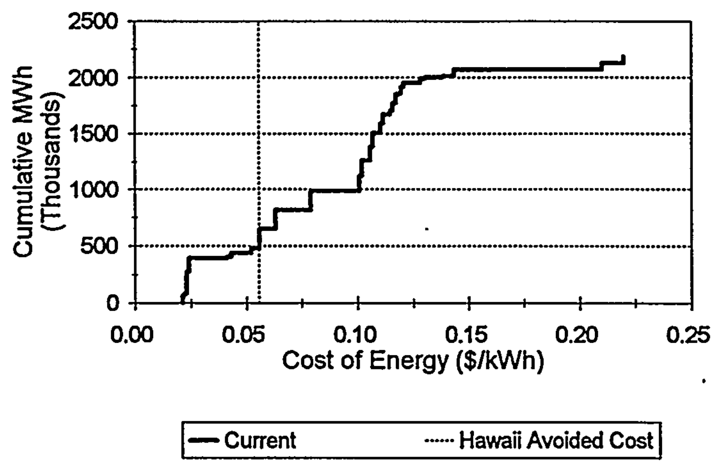
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Current	Incl	Nominal	15	1	30	56,905	0.0272
Wind		Hawaii	North Kohala	Current	Incl	Nominal	5	1	30	18,569	0.0281
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	50	1	30	154,183	0.0297
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	3	1	30	10,366	0.0301
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	30	1	30	92,510	0.0310
Wind		Hawaii	Kahua Ranch	Current	Incl	Nominal	5	1	30	10,516	0.0527
Wind		Hawaii	Kahua Ranch	Current	Incl	Nominal	15	1	30	30,396	0.0548
Hydro		Hawaii	Umauma Stream	Current	Incl	Nominal	13.8	2	50	40,199	0.0558
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Nominal	25	2	30	153,300	0.0805
Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Nominal	25	2	30	153,300	0.0847
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Current	Incl	Nominal	25	2	30	153,300	0.1053
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Nominal	50	4	30	119,968	0.1264
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Nominal	50	4	30	119,968	0.1278
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Nominal	15	1.5	30	28,015	0.1294
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Nominal	50	4	30	107,114	0.1328
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Nominal	5	1.5	30	9,433	0.1344
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Nominal	50	4	30	107,114	0.1344
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Nominal	30	1.5	30	52,500	0.1355
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Nominal	30	3	30	71,980	0.1386
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Nominal	30	3	30	71,980	0.1400
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Nominal	30	3	30	64,268	0.1459
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Nominal	30	3	30	64,268	0.1475
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Nominal	15	2.5	30	34,298	0.1519
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Nominal	15	2.5	30	30,623	0.1614
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Nominal	30	1.5	30	51,118	0.1629
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Nominal	5	1.5	30	11,433	0.1647
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Nominal	5	1.5	30	10,208	0.1753
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Nominal	30	1.5	30	56,086	0.2402
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Nominal	30	1.5	30	54,610	0.2514

Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Conservative	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0556



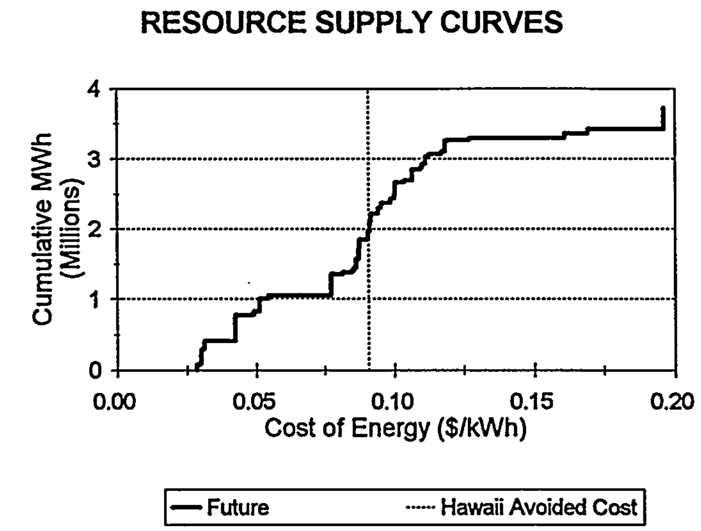
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Current	Incl	Conservative	15	1	30	48,105	0.0360
Wind		Hawaii	North Kohala	Current	Incl	Conservative	5	1	30	15,676	0.0376
Wind		Hawaii	Lalamilo Wells	Current	Incl	Conservative	50	1	30	129,123	0.0396
Wind		Hawaii	Lalamilo Wells	Current	Incl	Conservative	3	1	30	8,750	0.0404
Wind		Hawaii	Lalamilo Wells	Current	Incl	Conservative	30	1	30	77,474	0.0412
Hydro		Hawaii	Umauma Stream	Current	Incl	Conservative	13.8	2	50	39,788	0.0591
Wind		Hawaii	Kahua Ranch	Current	Incl	Conservative	5	1	30	8,838	0.0691
Wind		Hawaii	Kahua Ranch	Current	Incl	Conservative	15	1	30	25,475	0.0713
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Conservative	25	2	30	137,970	0.1107
Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Conservative	25	2	30	137,970	0.1111
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Current	Incl	Conservative	25	2	30	137,970	0.1373
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Conservative	50	4	30	107,971	0.1466
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Conservative	50	4	30	107,971	0.1483
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Conservative	15	1.5	30	25,213	0.1532
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Conservative	50	4	30	96,402	0.1539
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Conservative	50	4	30	96,402	0.1558
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Conservative	5	1.5	30	8,489	0.1592
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Conservative	30	3	30	64,782	0.1609
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Conservative	30	1.5	30	47,250	0.1612
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Conservative	30	3	30	64,782	0.1625
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Conservative	30	3	30	57,841	0.1692
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Conservative	30	3	30	57,841	0.1711
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Conservative	15	2.5	30	30,868	0.1760
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Conservative	15	2.5	30	27,561	0.1869
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Conservative	5	1.5	30	10,290	0.1914
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Conservative	30	1.5	30	46,006	0.1946
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Conservative	5	1.5	30	9,187	0.2035
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Conservative	30	1.5	30	50,477	0.2878
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Conservative	30	1.5	30	49,149	0.3014

Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Optimistic	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0556



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Current	Incl	Optimistic	15	1	30	66,395	0.0215
Wind		Hawaii	North Kohala	Current	Incl	Optimistic	5	1	30	21,693	0.0220
Wind		Hawaii	Lalamilo Wells	Current	Incl	Optimistic	50	1	30	181,386	0.0233
Wind		Hawaii	Lalamilo Wells	Current	Incl	Optimistic	3	1	30	12,109	0.0235
Wind		Hawaii	Lalamilo Wells	Current	Incl	Optimistic	30	1	30	108,832	0.0243
Wind		Hawaii	Kahua Ranch	Current	Incl	Optimistic	5	1	30	12,334	0.0414
Wind		Hawaii	Kahua Ranch	Current	Incl	Optimistic	15	1	30	35,735	0.0433
Hydro		Hawaii	Umauma Stream	Current	Incl	Optimistic	13.8	2	50	41,019	0.0522
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Current	Incl	Optimistic	25	2	30	168,630	0.0558
Biomass Elec	tree crops	Hawaii	Hilo Coast	Current	Incl	Optimistic	25	2	30	168,630	0.0632
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Current	Incl	Optimistic	25	2	30	168,630	0.0791
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Optimistic	50	4	30	137,963	0.1008
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Optimistic	50	4	30	137,963	0.1019
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Optimistic	50	4	30	123,181	0.1056
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Optimistic	50	4	30	123,181	0.1069
Photovoltaic	tracking	Hawaii	Keahole	Current	Incl	Optimistic	30	3	30	82,777	0.1103
Photovoltaic	tracking	Hawaii	Waikoloa	Current	Incl	Optimistic	30	3	30	82,777	0.1115
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Optimistic	15	1.5	30	29,416	0.1147
Photovoltaic	fixed	Hawaii	Keahole	Current	Incl	Optimistic	30	3	30	73,909	0.1158
Photovoltaic	fixed	Hawaii	Waikoloa	Current	Incl	Optimistic	30	3	30	73,909	0.1172
Solar Thermal	dish	Hawaii	N. Kohala	Current	Incl	Optimistic	5	1.5	30	9,904	0.1188
Solar Thermal	dish	Hawaii	Keahole	Current	Incl	Optimistic	30	1.5	30	55,125	0.1197
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Optimistic	15	2.5	30	39,442	0.1207
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Optimistic	15	2.5	30	35,216	0.1281
Photovoltaic	tracking	Hawaii	N. Kohala	Current	Incl	Optimistic	5	1.5	30	13,148	0.1303
Photovoltaic	fixed	Hawaii	N. Kohala	Current	Incl	Optimistic	5	1.5	30	11,739	0.1383
Solar Thermal	dish	Hawaii	Waikoloa	Current	Incl	Optimistic	30	1.5	30	53,674	0.1433
Solar Thermal	trough	Hawaii	Keahole	Current	Incl	Optimistic	30	1.5	30	58,890	0.2102
Solar Thermal	trough	Hawaii	Waikoloa	Current	Incl	Optimistic	30	1.5	30	57,340	0.2199

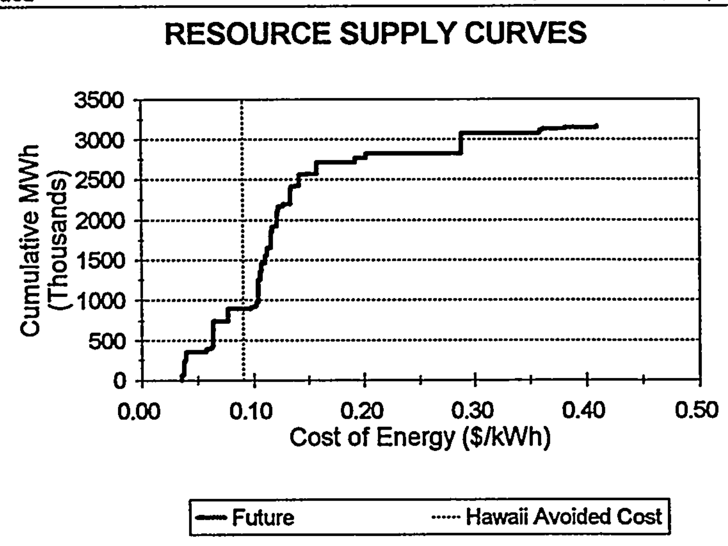
Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0906



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Nominal	15	1	30	71,178	0.0288
Wind		Hawaii	North Kohala	Future	Incl	Nominal	5	1	30	22,298	0.0297
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	50	1	30	192,086	0.0304
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	3	1	30	12,966	0.0309
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	30	1	30	115,714	0.0314
Geothermal		Hawaii	Kilauea	Future	Incl	Nominal	50	6	30	362,314	0.0425
Wind		Hawaii	Kahua Ranch	Future	Incl	Nominal	5	1	30	12,628	0.0480
Wind		Hawaii	Kahua Ranch	Future	Incl	Nominal	15	1	30	38,021	0.0492
Geothermal		Hawaii	Kilauea	Future	Incl	Nominal	25	5	30	177,302	0.0512
Hydro		Hawaii	Umauma Stream	Future	Incl	Nominal	13.8	2	50	40,199	0.0544
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Nominal	50	2	30	306,600	0.0772
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	29,416	0.0814
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Nominal	5	1.5	30	9,904	0.0845
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Nominal	30	1.5	30	55,125	0.0852
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Nominal	50	3	30	124,319	0.0862
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	2	30	153,300	0.0870
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Nominal	50	3	30	124,319	0.0873
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Nominal	50	3	30	110,999	0.0903
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Nominal	25	2	30	153,300	0.0911
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Nominal	50	3	30	110,999	0.0915
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Nominal	30	2	30	74,591	0.0942
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Nominal	30	2	30	74,591	0.0952
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Nominal	30	2	30	66,599	0.0988
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Nominal	30	2	30	66,599	0.1000
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Nominal	25	2	30	153,300	0.1003
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	35,542	0.1035
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	2	30	153,300	0.1064
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Nominal	15	1.5	30	31,734	0.1096
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Nominal	30	1.5	30	53,674	0.1103
Wave		Hawaii	N. Kohala	Future	Incl	Nominal	30	2	30	93,084	0.1112
Wave		Hawaii	Honokaa 2A	Future	Incl	Nominal	10	2	30	33,612	0.1125
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Nominal	5	1	30	11,847	0.1127
Wave		Hawaii	Pepeekeo 2E	Future	Incl	Nominal	10	2	30	32,389	0.1171
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Nominal	25	2	30	153,300	0.1183

Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Nominal	5	1	30	10,578	0.1194
Wave		Hawaii	N. Kohala	Future	Incl	Nominal	10	2	30	31,021	0.1271
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Nominal	30	1.5	30	64,499	0.1609
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Nominal	30	1.5	30	62,801	0.1694
OTEC		Hawaii	Keahole Point	Future	Incl	Nominal	60	2	30	296,438	0.1963

Island(s):	Hawaii		**Valuation:**	Constant Dollars
Technology:	All_Tech		**Financing:**	Utility
Certainty:	Conservative		**Tax Credits:**	Included
Stage:	Future Technology		**Data:**	All Data from Query
Trans. Cost:	Cost Included		**Avoided Cost:**	$0.0906

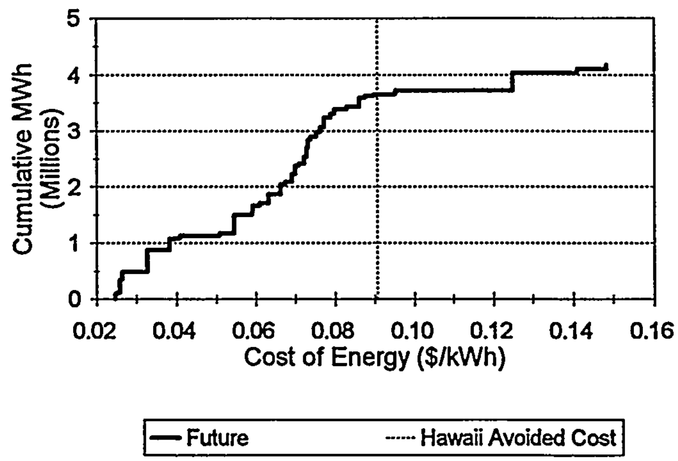


Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Conservative	15	1	30	60,171	0.0360
Wind		Hawaii	North Kohala	Future	Incl	Conservative	5	1	30	18,823	0.0376
Wind		Hawaii	Lalamilo Wells	Future	Incl	Conservative	50	1	30	160,865	0.0385
Wind		Hawaii	Lalamilo Wells	Future	Incl	Conservative	3	1	30	10,945	0.0393
Wind		Hawaii	Lalamilo Wells	Future	Incl	Conservative	30	1	30	96,907	0.0398
Hydro		Hawaii	Umauma Stream	Future	Incl	Conservative	13.8	2	50	39,788	0.0576
Wind		Hawaii	Kahua Ranch	Future	Incl	Conservative	5	1	30	10,612	0.0617
Wind		Hawaii	Kahua Ranch	Future	Incl	Conservative	15	1	30	31,865	0.0628
Geothermal		Hawaii	Kilauea	Future	Incl	Conservative	50	6	30	308,352	0.0641
Geothermal		Hawaii	Kilauea	Future	Incl	Conservative	25	5	30	150,672	0.0773
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Conservative	15	1.5	30	26,474	0.0978
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Conservative	5	1.5	30	8,914	0.1017
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Conservative	30	1.5	30	49,613	0.1031
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Conservative	50	2	30	275,940	0.1049
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Conservative	50	3	30	105,671	0.1060
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Conservative	50	3	30	105,671	0.1073
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Conservative	50	3	30	94,349	0.1109
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Conservative	50	3	30	94,349	0.1124
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Conservative	30	2	30	63,402	0.1158
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Conservative	25	2	30	137,970	0.1160
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Conservative	30	2	30	63,402	0.1171
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Conservative	30	2	30	56,609	0.1214
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Conservative	25	2	30	137,970	0.1215
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Conservative	30	2	30	56,609	0.1229
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Conservative	15	1.5	30	30,211	0.1270
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Conservative	30	1.5	30	48,307	0.1337
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Conservative	25	2	30	137,970	0.1337
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Conservative	15	1.5	30	26,974	0.1344
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Conservative	5	1	30	10,070	0.1388
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Conservative	25	2	30	137,970	0.1419
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Conservative	5	1	30	8,991	0.1471
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Conservative	25	2	30	137,970	0.1578
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Conservative	30	1.5	30	58,049	0.1922
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Conservative	30	1.5	30	56,521	0.2025

OTEC	Hawaii	Keahole Point	Future	Incl	Conservative	60	2	30	257,894	0.2887
Wave	Hawaii	N. Kohala	Future	Incl	Conservative	30	2	30	42,077	0.3596
Wave	Hawaii	Honokaa 2A	Future	Incl	Conservative	10	2	30	15,435	0.3619
Wave	Hawaii	Pepeekeo 2E	Future	Incl	Conservative	10	2	30	14,691	0.3811
Wave	Hawaii	N. Kohala	Future	Incl	Conservative	10	2	30	14,024	0.4103

Island(s):	**Hawaii**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Optimistic**	**Tax Credits:**	**Included**
Stage:	**Future Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0906**

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Optimistic	15	1	30	83,049	0.0247
Wind		Hawaii	North Kohala	Future	Incl	Optimistic	5	1	30	26,048	0.0253
Wind		Hawaii	Lalamilo Wells	Future	Incl	Optimistic	50	1	30	225,977	0.0258
Wind		Hawaii	Lalamilo Wells	Future	Incl	Optimistic	3	1	30	15,147	0.0261
Wind		Hawaii	Lalamilo Wells	Future	Incl	Optimistic	30	1	30	136,131	0.0266
Geothermal		Hawaii	Kilauea	Future	Incl	Optimistic	50	6	30	390,871	0.0328
Geothermal		Hawaii	Kilauea	Future	Incl	Optimistic	25	5	30	193,421	0.0384
Wind		Hawaii	Kahua Ranch	Future	Incl	Optimistic	5	1	30	14,811	0.0397
Wind		Hawaii	Kahua Ranch	Future	Incl	Optimistic	15	1	30	44,699	0.0409
Hydro		Hawaii	Umauma Stream	Future	Incl	Optimistic	13.8	2	50	41,019	0.0509
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Optimistic	50	2	30	337,260	0.0546
Wave		Hawaii	Honokaa 2A	Future	Incl	Optimistic	10	2	30	42,134	0.0591
Wave		Hawaii	N. Kohala	Future	Incl	Optimistic	30	2	30	117,856	0.0592
Wave		Hawaii	Pepeekeo 2E	Future	Incl	Optimistic	10	2	30	40,968	0.0610
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0633
Biomass Elec	tree crops	Hawaii	Hilo Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0663
Wave		Hawaii	N. Kohala	Future	Incl	Optimistic	10	2	30	39,276	0.0675
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Optimistic	50	3	30	142,967	0.0692
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Optimistic	50	3	30	142,967	0.0701
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Optimistic	15	1.5	30	30,886	0.0709
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Optimistic	50	3	30	127,649	0.0723
Biomass Elec	grass crops	Hawaii	Ka'u	Future	Incl	Optimistic	25	2	30	168,630	0.0729
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Optimistic	5	1.5	30	10,399	0.0733
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Optimistic	50	3	30	127,649	0.0733
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Optimistic	30	1.5	30	57,882	0.0738
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Optimistic	30	2	30	85,780	0.0754
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Optimistic	30	2	30	85,780	0.0763
Biomass Elec	grass crops	Hawaii	Hamakua Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0774
Photovoltaic	fixed	Hawaii	Keahole	Future	Incl	Optimistic	30	2	30	76,589	0.0789
Photovoltaic	fixed	Hawaii	Waikoloa	Future	Incl	Optimistic	30	2	30	76,589	0.0799
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Optimistic	15	1.5	30	40,873	0.0828
Biomass Elec	grass crops	Hawaii	Hilo Coast	Future	Incl	Optimistic	25	2	30	168,630	0.0861
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Optimistic	15	1.5	30	36,494	0.0876
Photovoltaic	tracking	Hawaii	N. Kohala	Future	Incl	Optimistic	5	1	30	13,624	0.0897

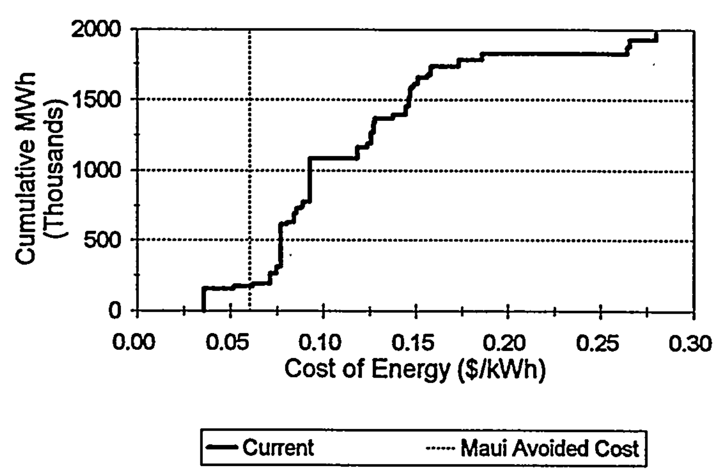
Photovoltaic	fixed	Hawaii	N. Kohala	Future	Incl	Optimistic	5	1	30	12,165	0.0949
Solar Thermal	dish	Hawaii	Waikoloa	Future	Incl	Optimistic	30	1.5	30	56,358	0.0953
OTEC		Hawaii	Keahole Point	Future	Incl	Optimistic	60	2	30	319,565	0.1249
Solar Thermal	trough	Hawaii	Keahole	Future	Incl	Optimistic	30	1.5	30	67,724	0.1411
Solar Thermal	trough	Hawaii	Waikoloa	Future	Incl	Optimistic	30	1.5	30	65,941	0.1483

APPENDIX B

RESOURCE SUPPLY CURVES, ISLAND OF MAUI

Island(s):	Maui	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0604

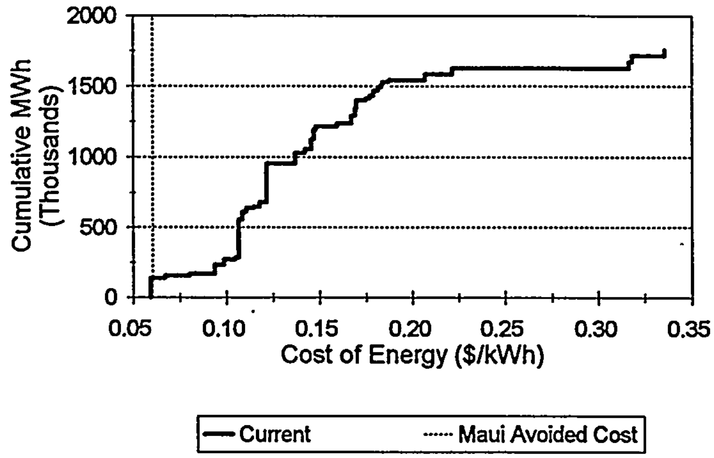
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Nominal	25	2	30	153,300	0.0357
Wind		Maui	McGregor Point	Current	Incl	Nominal	10	1	30	19,874	0.0515
Wind		Maui	NW Haleakala	Current	Incl	Nominal	10	1	30	17,124	0.0620
Wind		Maui	NW Haleakala	Current	Incl	Nominal	50	1	30	74,804	0.0713
Wind		Maui	NW Haleakala	Current	Incl	Nominal	30	1	30	44,882	0.0747
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Nominal	50	2	30	306,600	0.0772
Wind		Maui	Puunene	Current	Incl	Nominal	10	1	30	12,746	0.0805
Wind		Maui	West Maui	Current	Incl	Nominal	50	1	30	62,245	0.0843
Wind		Maui	West Maui	Current	Incl	Nominal	30	1	30	37,347	0.0858
Wind		Maui	West Maui	Current	Incl	Nominal	10	1	30	12,449	0.0885
Wind		Maui	Puunene	Current	Incl	Nominal	30	1	30	36,067	0.0895
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Nominal	50	2	30	306,600	0.0931
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Nominal	30	3	30	79,992	0.1186
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Nominal	10	2	30	28,158	0.1238
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Nominal	30	3	30	75,424	0.1259
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Nominal	30	3	30	75,069	0.1271
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Nominal	10	2	30	26,664	0.1279
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Nominal	10	2	30	25,023	0.1376
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Nominal	30	3	30	61,532	0.1446
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Nominal	30	3	30	61,532	0.1462
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Nominal	30	3	30	61,320	0.1468
Solar Thermal	dish	Maui	Puunene	Current	Incl	Nominal	10	1.5	30	15,648	0.1474
Solar Thermal	dish	Maui	Kihei	Current	Incl	Nominal	10	1.5	30	16,116	0.1489
Solar Thermal	dish	Maui	Puunene	Current	Incl	Nominal	30	1.5	30	46,471	0.1508
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Nominal	10	2	30	20,511	0.1563
Solar Thermal	dish	Maui	Kahului	Current	Incl	Nominal	10	1.5	30	15,179	0.1578
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Nominal	10	2	30	20,511	0.1579
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Nominal	10	2	30	20,440	0.1585
Solar Thermal	dish	Maui	Kihei	Current	Incl	Nominal	30	1.5	30	47,862	0.1737
Solar Thermal	dish	Maui	Kahului	Current	Incl	Nominal	30	1.5	30	45,080	0.1862
Solar Thermal	trough	Maui	Kihei	Current	Incl	Nominal	30	1.5	30	51,131	0.2646
Solar Thermal	trough	Maui	Puunene	Current	Incl	Nominal	30	1.5	30	49,645	0.2659
Solar Thermal	trough	Maui	Kahului	Current	Incl	Nominal	30	1.5	30	48,159	0.2803

Island(s):	**Maui**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Conservative**	**Tax Credits:**	**Included**
Stage:	**Current Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0604**

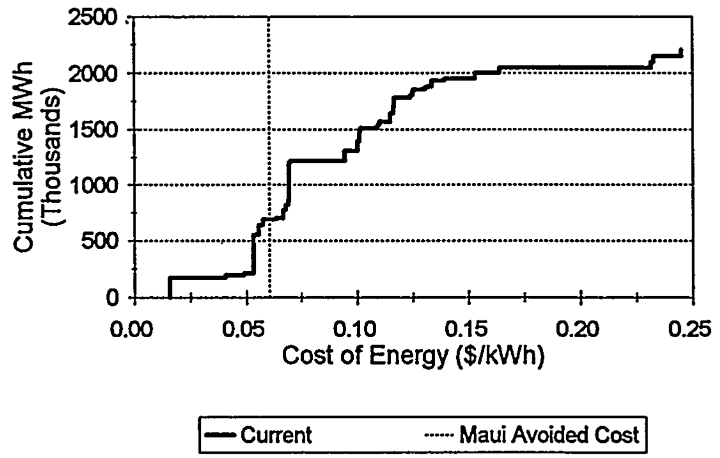
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Conservative	25	2	30	137,970	0.0597
Wind		Maui	McGregor Point	Current	Incl	Conservative	10	1	30	16,801	0.0669
Wind		Maui	NW Haleakala	Current	Incl	Conservative	10	1	30	14,476	0.0803
Wind		Maui	NW Haleakala	Current	Incl	Conservative	50	1	30	62,645	0.0935
Wind		Maui	NW Haleakala	Current	Incl	Conservative	30	1	30	37,587	0.0986
Wind		Maui	Puunene	Current	Incl	Conservative	10	1	30	10,720	0.1043
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Conservative	50	2	30	275,940	0.1063
Wind		Maui	West Maui	Current	Incl	Conservative	50	1	30	52,349	0.1085
Wind		Maui	West Maui	Current	Incl	Conservative	30	1	30	31,409	0.1105
Wind		Maui	West Maui	Current	Incl	Conservative	10	1	30	10,470	0.1143
Wind		Maui	Puunene	Current	Incl	Conservative	30	1	30	30,204	0.1179
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Conservative	50	2	30	275,940	0.1218
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Conservative	30	3	30	71,992	0.1372
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Conservative	10	2	30	25,343	0.1424
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Conservative	30	3	30	67,881	0.1457
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Conservative	30	3	30	67,562	0.1471
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Conservative	10	2	30	23,994	0.1483
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Conservative	10	2	30	22,521	0.1596
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Conservative	30	3	30	55,379	0.1672
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Conservative	30	3	30	55,379	0.1692
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Conservative	30	3	30	55,188	0.1698
Solar Thermal	dish	Maui	Puunene	Current	Incl	Conservative	10	1.5	30	14,083	0.1748
Solar Thermal	dish	Maui	Kihei	Current	Incl	Conservative	10	1.5	30	14,505	0.1767
Solar Thermal	dish	Maui	Puunene	Current	Incl	Conservative	30	1.5	30	41,824	0.1788
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Conservative	10	2	30	18,460	0.1812
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Conservative	10	2	30	18,460	0.1830
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Conservative	10	2	30	18,396	0.1838
Solar Thermal	dish	Maui	Kahului	Current	Incl	Conservative	10	1.5	30	13,661	0.1874
Solar Thermal	dish	Maui	Kihei	Current	Incl	Conservative	30	1.5	30	43,076	0.2069
Solar Thermal	dish	Maui	Kahului	Current	Incl	Conservative	30	1.5	30	40,572	0.2219
Solar Thermal	trough	Maui	Kihei	Current	Incl	Conservative	30	1.5	30	46,018	0.3169
Solar Thermal	trough	Maui	Puunene	Current	Incl	Conservative	30	1.5	30	44,681	0.3184
Solar Thermal	trough	Maui	Kahului	Current	Incl	Conservative	30	1.5	30	43,343	0.3358

Island(s):	Maui	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Optimistic	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0604

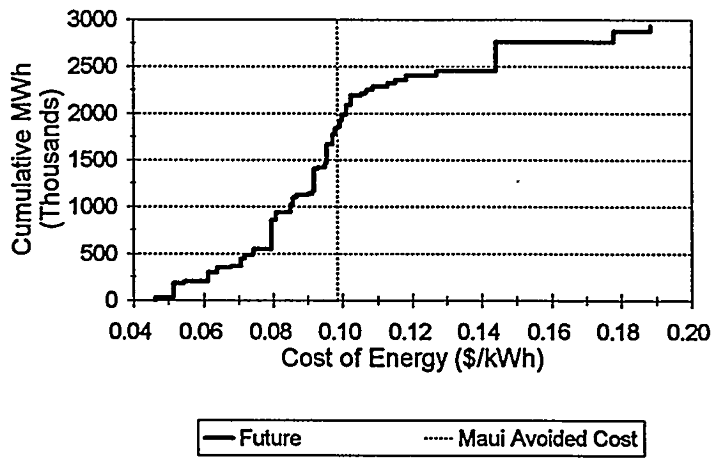
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Optimistic	25	2	30	168,630	0.0160
Wind		Maui	McGregor Point	Current	Incl	Optimistic	10	1	30	23,189	0.0408
Wind		Maui	NW Haleakala	Current	Incl	Optimistic	10	1	30	19,980	0.0492
Biomass Elec	tree crops	Maui	Paia-Puunene	Current	Incl	Optimistic	50	2	30	337,260	0.0534
Wind		Maui	NW Haleakala	Current	Incl	Optimistic	50	1	30	88,001	0.0556
Wind		Maui	NW Haleakala	Current	Incl	Optimistic	30	1	30	52,801	0.0577
Wind		Maui	Puunene	Current	Incl	Optimistic	10	1	30	14,940	0.0636
Wind		Maui	West Maui	Current	Incl	Optimistic	50	1	30	72,957	0.0670
Wind		Maui	West Maui	Current	Incl	Optimistic	30	1	30	43,774	0.0681
Wind		Maui	Puunene	Current	Incl	Optimistic	30	1	30	42,430	0.0691
Biomass Elec	grass crops	Maui	Paia-Puunene	Current	Incl	Optimistic	50	2	30	337,260	0.0697
Wind		Maui	West Maui	Current	Incl	Optimistic	10	1	30	14,591	0.0701
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Optimistic	30	3	30	91,990	0.0944
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Optimistic	30	3	30	86,737	0.1002
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Optimistic	30	3	30	86,330	0.1012
Photovoltaic	tracking	Maui	Kahului	Current	Incl	Optimistic	10	2	30	30,664	0.1014
Photovoltaic	tracking	Maui	Puunene	Current	Incl	Optimistic	10	2	30	28,776	0.1091
Photovoltaic	tracking	Maui	Kihei	Current	Incl	Optimistic	10	2	30	28,912	0.1101
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Optimistic	30	3	30	70,762	0.1149
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Optimistic	30	3	30	70,762	0.1162
Photovoltaic	fixed	Maui	Kihei	Current	Incl	Optimistic	30	3	30	70,518	0.1167
Photovoltaic	fixed	Maui	Puunene	Current	Incl	Optimistic	10	2	30	23,587	0.1237
Photovoltaic	fixed	Maui	Kahului	Current	Incl	Optimistic	10	2	30	23,587	0.1250
Photovoltaic	fixed.	Maui	Kihei	Current	Incl	Optimistic	10	2	30	23,506	0.1255
Solar Thermal	dish	Maui	Puunene	Current	Incl	Optimistic	10	1.5	30	16,430	0.1305
Solar Thermal	dish	Maui	Kihei	Current	Incl	Optimistic	10	1.5	30	16,922	0.1316
Solar Thermal	dish	Maui	Puunene	Current	Incl	Optimistic	30	1.5	30	48,795	0.1336
Solar Thermal	dish	Maui	Kahului	Current	Incl	Optimistic	10	1.5	30	15,938	0.1395
Solar Thermal	dish	Maui	Kihei	Current	Incl	Optimistic	30	1.5	30	50,256	0.1531
Solar Thermal	dish	Maui	Kahului	Current	Incl	Optimistic	30	1.5	30	47,334	0.1640
Solar Thermal	trough	Maui	Kihei	Current	Incl	Optimistic	30	1.5	30	53,688	0.2318
Solar Thermal	trough	Maui	Puunene	Current	Incl	Optimistic	30	1.5	30	52,127	0.2330
Solar Thermal	trough	Maui	Kahului	Current	Incl	Optimistic	30	1.5	30	50,567	0.2454

Island(s):	Maui	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0984

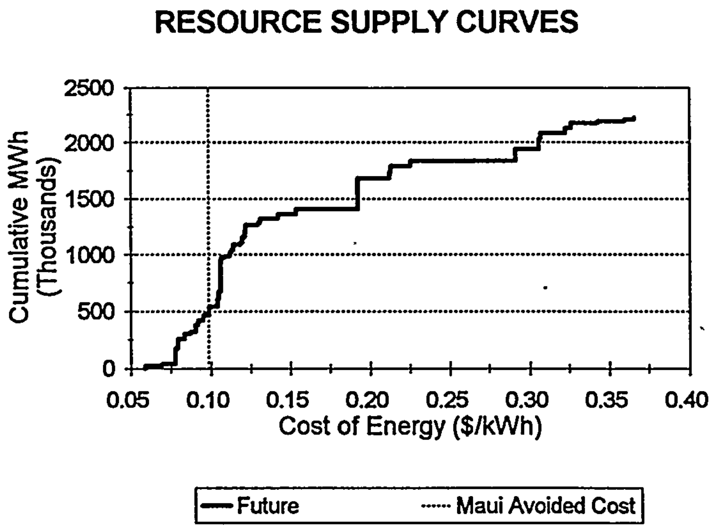
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Maui	McGregor Point	Future	Incl	Nominal	10	1	30	24,611	0.0465
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Nominal	25	2	30	153,300	0.0515
Wind		Maui	NW Haleakala	Future	Incl	Nominal	10	1	30	21,205	0.0545
Wind		Maui	NW Haleakala	Future	Incl	Nominal	50	1	30	93,192	0.0613
Wind		Maui	NW Haleakala	Future	Incl	Nominal	30	1	30	56,140	0.0639
Wind		Maui	Puunene	Future	Incl	Nominal	10	1	30	15,784	0.0677
Wind		Maui	West Maui	Future	Incl	Nominal	50	1	30	77,546	0.0707
Wind		Maui	West Maui	Future	Incl	Nominal	30	1	30	46,715	0.0718
Wind		Maui	West Maui	Future	Incl	Nominal	10	1	30	15,416	0.0741
Wind		Maui	Puunene	Future	Incl	Nominal	30	1	30	45,113	0.0743
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	2	30	306,600	0.0795
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Nominal	30	2	30	82,893	0.0807
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Nominal	30	2	30	77,792	0.0850
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Nominal	30	2	30	78,159	0.0857
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Nominal	10	1	30	27,632	0.0866
Solar Thermal	dish	Maui	Puunene	Future	Incl	Nominal	10	1.5	30	16,430	0.0901
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Nominal	10	1	30	25,931	0.0913
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Nominal	10	1	30	26,053	0.0919
Wave		Maui	Opana Point	Future	Incl	Nominal	60	2	30	211,984	0.0920
Solar Thermal	dish	Maui	Kihei	Future	Incl	Nominal	10	1.5	30	16,922	0.0929
Solar Thermal	dish	Maui	Puunene	Future	Incl	Nominal	30	1.5	30	48,795	0.0949
Wave		Maui	Lower Paia	Future	Incl	Nominal	60	2	30	203,974	0.0956
Wave		Maui	Opana Point	Future	Incl	Nominal	30	2	30	106,004	0.0972
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Nominal	30	2	30	63,764	0.0980
Solar Thermal	dish	Maui	Kahului	Future	Incl	Nominal	10	1.5	30	15,938	0.0984
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Nominal	30	2	30	63,764	0.0992
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Nominal	30	2	30	63,544	0.0997
Wave		Maui	Lower Paia	Future	Incl	Nominal	30	2	30	101,998	0.1010
Wave		Maui	Waiehu Point	Future	Incl	Nominal	30	2	30	101,256	0.1023
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Nominal	10	1	30	21,255	0.1053
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Nominal	10	1	30	21,255	0.1065
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Nominal	10	1	30	21,181	0.1069
Wave		Maui	Opana Point	Future	Incl	Nominal	10	2	30	35,321	0.1086
Wave		Maui	Lower Paia	Future	Incl	Nominal	10	2	30	33,987	0.1129

Wave		Maui	Waiehu Point	Future	Incl	Nominal	10	2	30	33,733	0.1151
Solar Thermal	dish	Maui	Kihei	Future	Incl	Nominal	30	1.5	30	50,256	0.1181
Solar Thermal	dish	Maui	Kahului	Future	Incl	Nominal	30	1.5	30	47,334	0.1271
Biomass Elec	grass crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	2	30	306,600	0.1442
Solar Thermal	trough	Maui	Puunene	Future	Incl	Nominal	30	1.5	30	57,092	0.1778
Solar Thermal	trough	Maui	Kihei	Future	Incl	Nominal	30	1.5	30	58,801	0.1781
Solar Thermal	trough	Maui	Kahului	Future	Incl	Nominal	30	1.5	30	55,382	0.1886

Island(s):	**Maui**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Conservative**	**Tax Credits:**	**Included**
Stage:	**Future Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0984**

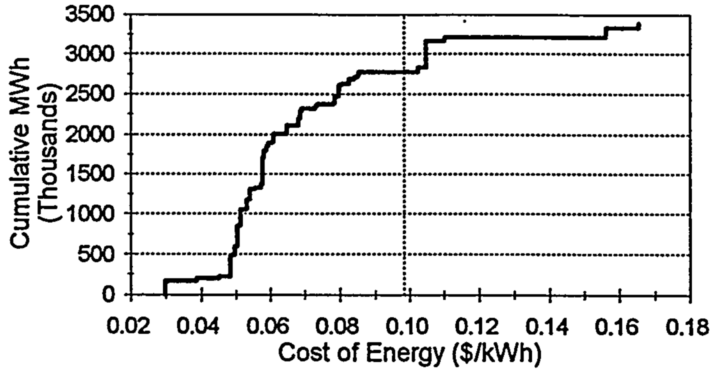


Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Maui	McGregor Point	Future	Incl	Conservative	10	1	30	20,805	0.0592
Wind		Maui	NW Haleakala	Future	Incl	Conservative	10	1	30	17,926	0.0695
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Conservative	25	2	30	137,970	0.0779
Wind		Maui	NW Haleakala	Future	Incl	Conservative	50	1	30	78,045	0.0795
Wind		Maui	NW Haleakala	Future	Incl	Conservative	30	1	30	47,015	0.0834
Wind		Maui	Puunene	Future	Incl	Conservative	10	1	30	13,275	0.0872
Wind		Maui	West Maui	Future	Incl	Conservative	50	1	30	65,218	0.0905
Wind		Maui	West Maui	Future	Incl	Conservative	30	1	30	39,288	0.0920
Wind		Maui	West Maui	Future	Incl	Conservative	10	1	30	12,965	0.0953
Wind		Maui	Puunene	Future	Incl	Conservative	30	1	30	37,781	0.0954
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Conservative	30	2	30	70,459	0.0990
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Conservative	30	2	30	66,123	0.1042
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Conservative	30	2	30	66,435	0.1051
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Conservative	50	2	30	275,940	0.1060
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Conservative	10	1	30	23,487	0.1064
Solar Thermal	dish	Maui	Puunene	Future	Incl	Conservative	10	1.5	30	14,787	0.1085
Solar Thermal	dish	Maui	Kihei	Future	Incl	Conservative	10	1.5	30	15,230	0.1119
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Conservative	10	1	30	22,041	0.1122
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Conservative	10	1	30	22,145	0.1130
Solar Thermal	dish	Maui	Puunene	Future	Incl	Conservative	30	1.5	30	43,915	0.1143
Solar Thermal	dish	Maui	Kahului	Future	Incl	Conservative	10	1.5	30	14,344	0.1187
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Conservative	30	2	30	54,199	0.1200
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Conservative	30	2	30	54,199	0.1216
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Conservative	30	2	30	54,012	0.1221
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Conservative	10	1	30	18,066	0.1294
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Conservative	10	1	30	18,067	0.1308
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Conservative	10	1	30	18,004	0.1314
Solar Thermal	dish	Maui	Kihei	Future	Incl	Conservative	30	1.5	30	45,230	0.1426
Solar Thermal	dish	Maui	Kahului	Future	Incl	Conservative	30	1.5	30	42,600	0.1536
Biomass Elec	grass crops	Maui	Paia-Puunene	Future	Incl	Conservative	50	2	30	275,940	0.1922
Solar Thermal	trough	Maui	Puunene	Future	Incl	Conservative	30	1.5	30	51,383	0.2122
Solar Thermal	trough	Maui	Kihei	Future	Incl	Conservative	30	1.5	30	52,921	0.2127
Solar Thermal	trough	Maui	Kahului	Future	Incl	Conservative	30	1.5	30	49,844	0.2254
Wave		Maui	Opana Point	Future	Incl	Conservative	60	2	30	98,882	0.2913

Wave	Maui	Lower Paia	Future	Incl	Conservative	60	2	30	94,151	0.3060
Wave	Maui	Opana Point	Future	Incl	Conservative	30	2	30	49,444	0.3069
Wave	Maui	Lower Paia	Future	Incl	Conservative	30	2	30	47,078	0.3224
Wave	Maui	Waiehu Point	Future	Incl	Conservative	30	2	30	46,754	0.3260
Wave	Maui	Opana Point	Future	Incl	Conservative	10	2	30	16,478	0.3429
Wave	Maui	Lower Paia	Future	Incl	Conservative	10	2	30	15,690	0.3602
Wave	Maui	Waiehu Point	Future	Incl	Conservative	10	2	30	15,580	0.3661

Island(s):	Maui	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Optimistic	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0984

RESOURCE SUPPLY CURVES



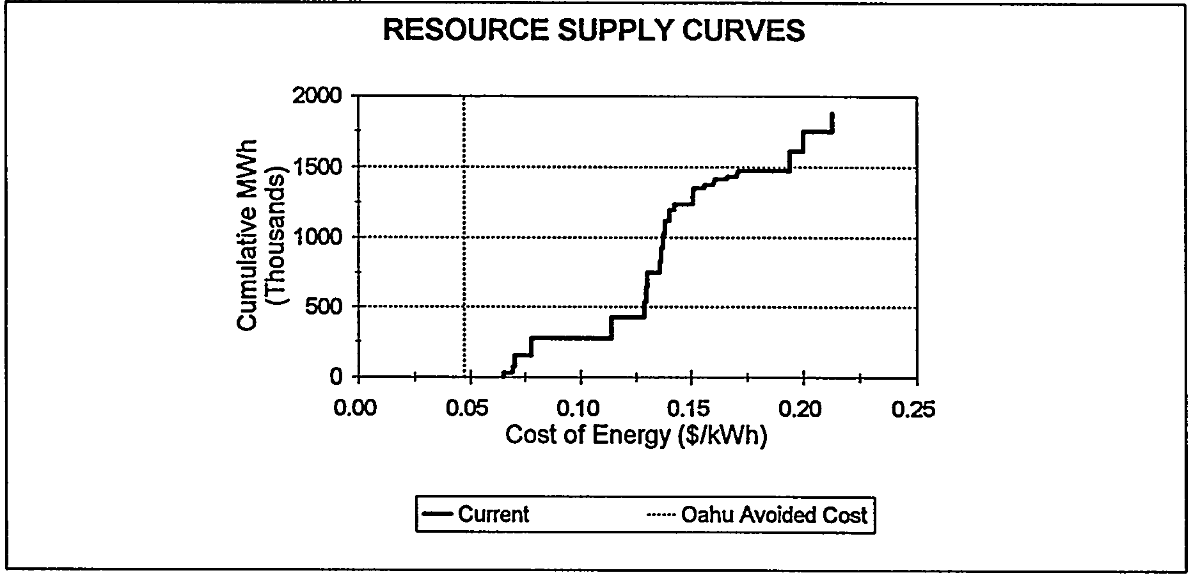
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Optimistic	25	2	30	168,630	0.0299
Wind		Maui	McGregor Point	Future	Incl	Optimistic	10	1	30	28,715	0.0388
Wind		Maui	NW Haleakala	Future	Incl	Optimistic	10	1	30	24,741	0.0452
Wave		Maui	Opana Point	Future	Incl	Optimistic	60	2	30	265,780	0.0485
Wind		Maui	NW Haleakala	Future	Incl	Optimistic	50	1	30	109,635	0.0498
Wave		Maui	Lower Paia	Future	Incl	Optimistic	60	2	30	255,885	0.0504
Wave		Maui	Opana Point	Future	Incl	Optimistic	30	2	30	132,906	0.0513
Wind		Maui	NW Haleakala	Future	Incl	Optimistic	30	1	30	66,045	0.0515
Wave		Maui	Lower Paia	Future	Incl	Optimistic	30	2	30	127,957	0.0533
Wave		Maui	Waiehu Point	Future	Incl	Optimistic	30	2	30	126,887	0.0542
Wind		Maui	Puunene	Future	Incl	Optimistic	10	1	30	18,501	0.0555
Wave		Maui	Opana Point	Future	Incl	Optimistic	10	2	30	44,283	0.0573
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Optimistic	50	2	30	337,260	0.0578
Wind		Maui	West Maui	Future	Incl	Optimistic	50	1	30	90,891	0.0581
Wind		Maui	West Maui	Future	Incl	Optimistic	30	1	30	54,754	0.0589
Wave		Maui	Lower Paia	Future	Incl	Optimistic	10	2	30	42,635	0.0596
Wind		Maui	West Maui	Future	Incl	Optimistic	10	1	30	18,069	0.0607
Wind		Maui	Puunene	Future	Incl	Optimistic	30	1	30	53,073	0.0609
Wave		Maui	Waiehu Point	Future	Incl	Optimistic	10	2	30	42,269	0.0610
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Optimistic	30	2	30	95,327	0.0647
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Optimistic	30	2	30	89,461	0.0682
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Optimistic	30	2	30	89,883	0.0687
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Optimistic	10	1	30	31,776	0.0691
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Optimistic	10	1	30	29,821	0.0729
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Optimistic	10	1	30	29,961	0.0734
Solar Thermal	dish	Maui	Puunene	Future	Incl	Optimistic	10	1.5	30	17,252	0.0781
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Optimistic	30	2	30	73,329	0.0784
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Optimistic	30	2	30	73,329	0.0795
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Optimistic	30	2	30	73,076	0.0798
Solar Thermal	dish	Maui	Kihei	Future	Incl	Optimistic	10	1.5	30	17,768	0.0805
Solar Thermal	dish	Maui	Puunene	Future	Incl	Optimistic	30	1.5	30	51,234	0.0825
Photovoltaic	fixed	Maui	Puunene	Future	Incl	Optimistic	10	1	30	24,443	0.0839
Photovoltaic	fixed	Maui	Kahului	Future	Incl	Optimistic	10	1	30	24,443	0.0849
Photovoltaic	fixed	Maui	Kihei	Future	Incl	Optimistic	10	1	30	24,359	0.0853

Solar Thermal	dish	Maui	Kahului	Future	Incl	Optimistic	10	1.5	30	16,735	0.0853
Solar Thermal	dish	Maui	Kihei	Future	Incl	Optimistic	30	1.5	30	52,768	0.1023
Biomass Elec	grass crops	Maui	Pala-Puunene	Future	Incl	Optimistic	50	2	30	337,260	0.1049
Solar Thermal	dish	Maui	Kahului	Future	Incl	Optimistic	30	1.5	30	49,700	0.1101
Solar Thermal	trough	Maui	Puunene	Future	Incl	Optimistic	30	1.5	30	59,946	0.1562
Solar Thermal	trough	Maui	Kihei	Future	Incl	Optimistic	30	1.5	30	61,741	0.1564
Solar Thermal	trough	Maui	Kahului	Future	Incl	Optimistic	30	1.5	30	58,152	0.1656

APPENDIX C

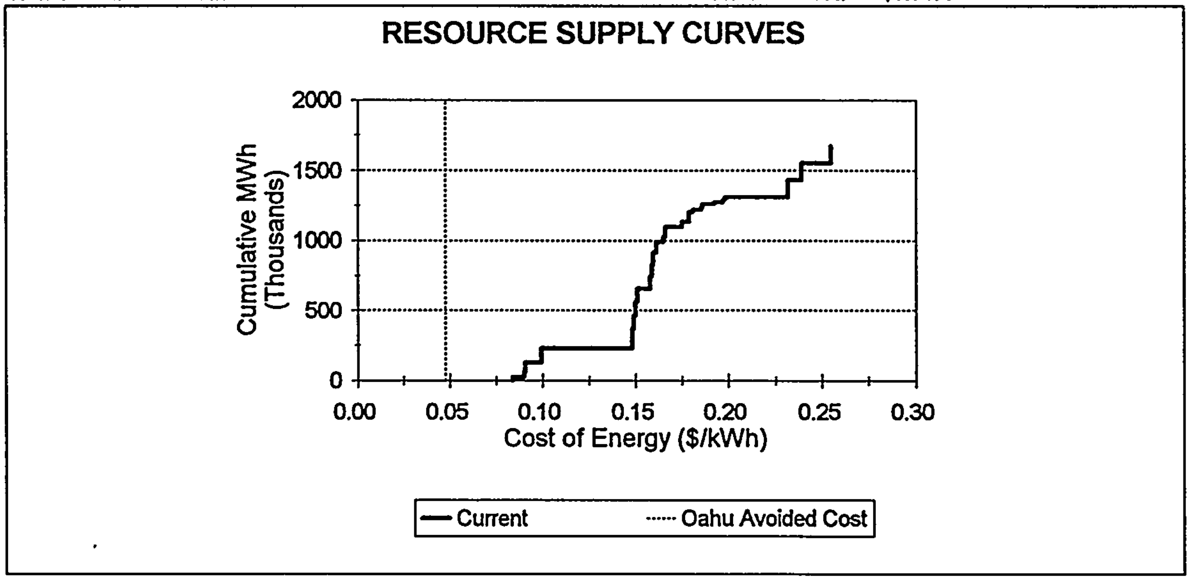
RESOURCE SUPPLY CURVES, ISLAND OF OAHU

Island(s):	Oahu	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0473



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Oahu	Kaena Point	Current	Incl	Nominal	15	1	30	25,230	0.0652
Wind		Oahu	Kaena Point	Current	Incl	Nominal	2	1	30	3,555	0.0687
Wind		Oahu	Kahuku	Current	Incl	Nominal	30	1	30	45,551	0.0694
Wind		Oahu	Kahuku	Current	Incl	Nominal	50	1	30	75,918	0.0703
Wind		Oahu	Kahuku	Current	Incl	Nominal	80	1	30	121,469	0.0777
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Nominal	25	2	30	153,300	0.1139
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Nominal	50	4	30	107,766	0.1288
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Nominal	50	4	30	107,766	0.1297
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	4	30	107,766	0.1303
Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Nominal	50	1.5	30	80,904	0.1360
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Nominal	50	4	30	96,220	0.1364
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Nominal	50	4	30	96,220	0.1373
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	4	30	96,220	0.1381
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Nominal	50	1.5	30	77,059	0.1403
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Nominal	20	3	30	43,107	0.1425
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Nominal	50	1.5	30	74,752	0.1509
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Nominal	20	3	30	38,488	0.1511
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Nominal	10	2	30	21,553	0.1563
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Nominal	10	2	30	21,553	0.1601
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Nominal	10	2	30	21,553	0.1607
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Nominal	10	2	30	19,244	0.1661
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Nominal	10	2	30	19,244	0.1704
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Nominal	10	2	30	19,244	0.1711
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Nominal	80	1.5	30	139,601	0.1939
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Nominal	80	1.5	30	132,966	0.2001
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Nominal	80	1.5	30	128,985	0.2130

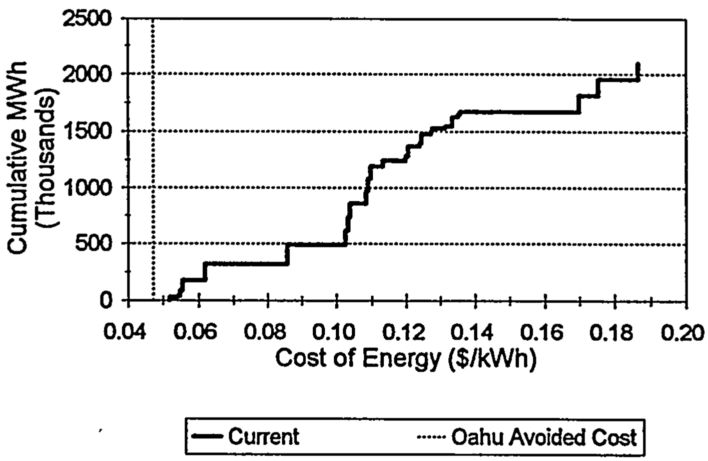
Island(s):	Oahu	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Conservative	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0473



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Oahu	Kaena Point	Current	Incl	Conservative	15	1	30	21,234	0.0841
Wind		Oahu	Kaena Point	Current	Incl	Conservative	2	1	30	3,003	0.0899
Wind		Oahu	Kahuku	Current	Incl	Conservative	30	1	30	38,147	0.0901
Wind		Oahu	Kahuku	Current	Incl	Conservative	50	1	30	63,579	0.0910
Wind		Oahu	Kahuku	Current	Incl	Conservative	80	1	30	101,726	0.0998
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Conservative	25	2	30	137,970	0.1483
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Conservative	50	4	30	96,990	0.1491
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Conservative	50	4	30	96,990	0.1501
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Conservative	50	4	30	96,990	0.1509
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Conservative	50	4	30	86,598	0.1577
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Conservative	50	4	30	86,598	0.1588
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Conservative	50	4	30	86,598	0.1597
Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Conservative	50	1.5	30	72,814	0.1612
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Conservative	20	3	30	38,796	0.1651
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Conservative	50	1.5	30	69,353	0.1661
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Conservative	20	3	30	34,639	0.1750
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Conservative	50	1.5	30	67,276	0.1791
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Conservative	10	2	30	19,398	0.1812
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Conservative	10	2	30	19,398	0.1856
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Conservative	10	2	30	19,398	0.1863
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Conservative	10	2	30	17,320	0.1925
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Conservative	10	2	30	17,320	0.1974
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Conservative	10	2	30	17,320	0.1982
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Conservative	80	1.5	30	125,641	0.2317
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Conservative	80	1.5	30	119,669	0.2391
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Conservative	80	1.5	30	116,086	0.2548

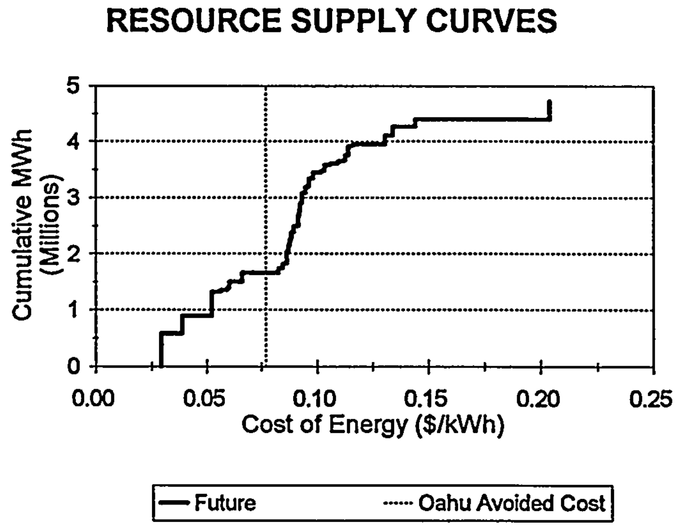
Island(s):	Oahu	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Optimistic	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0473

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Oahu	Kaena Point	Current	Incl	Optimistic	15	1	30	29,553	0.0518
Wind		Oahu	Kaena Point	Current	Incl	Optimistic	2	1	30	4,151	0.0539
Wind		Oahu	Kahuku	Current	Incl	Optimistic	30	1	30	53,588	0.0548
Wind		Oahu	Kahuku	Current	Incl	Optimistic	50	1	30	89,313	0.0556
Wind		Oahu	Kahuku	Current	Incl	Optimistic	80	1	30	142,900	0.0620
Biomass Elec	grass crops	Oahu	Waialua	Current	Incl	Optimistic	25	2	30	168,630	0.0857
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Optimistic	50	4	30	123,931	0.1026
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Optimistic	50	4	30	123,931	0.1032
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Optimistic	50	4	30	123,931	0.1038
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Optimistic	50	4	30	110,654	0.1084
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Optimistic	50	4	30	110,654	0.1091
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Optimistic	50	4	30	110,654	0.1097
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Optimistic	20	3	30	49,573	0.1131
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Optimistic	20	3	30	44,261	0.1198
Solar Thermal	dish	Oahu	Pearl Harbor	Current	Incl	Optimistic	50	1.5	30	84,949	0.1205
Photovoltaic	tracking	Oahu	Lualualei	Current	Incl	Optimistic	10	2	30	24,786	0.1239
Solar Thermal	dish	Oahu	Lualualei	Current	Incl	Optimistic	50	1.5	30	80,912	0.1243
Photovoltaic	tracking	Oahu	Pearl Harbor	Current	Incl	Optimistic	10	2	30	24,786	0.1272
Photovoltaic	tracking	Oahu	N. Ewa Plain	Current	Incl	Optimistic	10	2	30	24,786	0.1277
Photovoltaic	fixed	Oahu	Lualualei	Current	Incl	Optimistic	10	2	30	22,131	0.1314
Solar Thermal	dish	Oahu	N. Ewa Plain	Current	Incl	Optimistic	50	1.5	30	78,489	0.1335
Photovoltaic	fixed	Oahu	Pearl Harbor	Current	Incl	Optimistic	10	2	30	22,131	0.1351
Photovoltaic	fixed	Oahu	N. Ewa Plain	Current	Incl	Optimistic	10	2	30	22,131	0.1357
Solar Thermal	trough	Oahu	Pearl Harbor	Current	Incl	Optimistic	80	1.5	30	146,581	0.1700
Solar Thermal	trough	Oahu	Lualualei	Current	Incl	Optimistic	80	1.5	30	139,614	0.1755
Solar Thermal	trough	Oahu	N. Ewa Plain	Current	Incl	Optimistic	80	1.5	30	135,434	0.1866

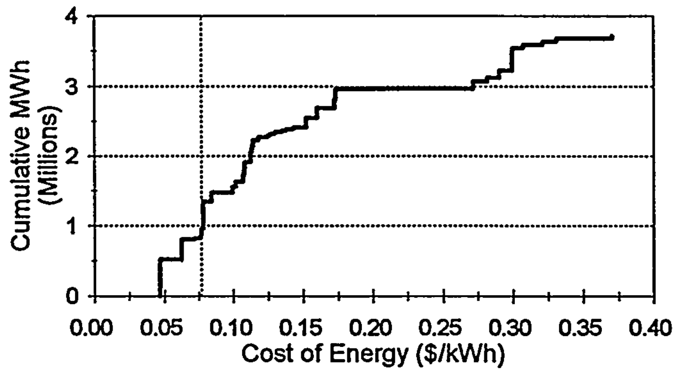
Island(s):	Oahu		Valuation:	Constant Dollars
Technology:	All Technologies		Financing:	Utility
Stage:	Future Technology		Tax Credits:	Included
Certainty:	Nominal		Data:	All Data from Query
Trans. Cost:	Cost Included		Avoided Cost:	$0.0770



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Nominal	50	2	30	306,600	0.0389
Wind		Oahu	Kaena Point	Future	Incl	Nominal	15	1	30	31,558	0.0567
Wind		Oahu	Kahuku	Future	Incl	Nominal	30	1	30	56,977	0.0597
Wind		Oahu	Kahuku	Future	Incl	Nominal	50	1	30	94,581	0.0605
Wind		Oahu	Kaena Point	Future	Incl	Nominal	2	1	30	4,002	0.0617
Wind		Oahu	Kahuku	Future	Incl	Nominal	80	1	30	151,558	0.0664
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Nominal	50	1.5	30	84,949	0.0829
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Nominal	50	1.5	30	80,912	0.0846
Wave		Oahu	Makapuu	Future	Incl	Nominal	60	2	30	224,378	0.0863
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Nominal	50	3	30	111,675	0.0873
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Nominal	50	3	30	111,675	0.0878
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	3	30	111,675	0.0883
Wave		Oahu	Makapuu	Future	Incl	Nominal	30	2	30	112,208	0.0898
Wave		Oahu	Kahuku Point	Future	Incl	Nominal	60	2	30	211,197	0.0918
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Nominal	50	3	30	99,710	0.0921
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Nominal	50	3	30	99,710	0.0926
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	3	30	99,710	0.0932
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Nominal	50	1.5	30	78,489	0.0933
Wave		Oahu	Kahuku Point	Future	Incl	Nominal	30	2	30	105,608	0.0947
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Nominal	20	2	30	44,670	0.0962
Wave		Oahu	NE Coast 2A	Future	Incl	Nominal	30	2	30	103,704	0.0966
Wave		Oahu	NE Coast 2C	Future	Incl	Nominal	30	2	30	101,831	0.0982
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Nominal	20	2	30	39,884	0.1016
Wave		Oahu	Mokapu Point	Future	Incl	Nominal	30	2	30	97,966	0.1034
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Nominal	10	1	30	22,335	0.1056
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Nominal	10	1	30	22,335	0.1091
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Nominal	10	1	30	22,335	0.1095
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Nominal	10	1	30	19,942	0.1119
Wave		Oahu	Waimanalo Bay	Future	Incl	Nominal	30	2	30	88,957	0.1128
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Nominal	25	2	30	153,300	0.1141
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Nominal	10	1	30	19,942	0.1157
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Nominal	10	1	30	19,942	0.1162
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Nominal	80	1.5	30	160,541	0.1307
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Nominal	80	1.5	30	152,911	0.1343
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Nominal	80	1.5	30	148,333	0.1443
OTEC		Oahu	Kahe Point	Future	Incl	Nominal	60	2	30	311,260	0.2041

Island(s):	Oahu	Valuation:	Constant Dollars
Technology:	All Technologies	Financing:	Utility
Stage:	Future Technology	Tax Credits:	Included
Certainty:	Conservative	Data:	All Data from Query
Trans. Cost:	Cost Included	Avoided Cost:	$0.0770

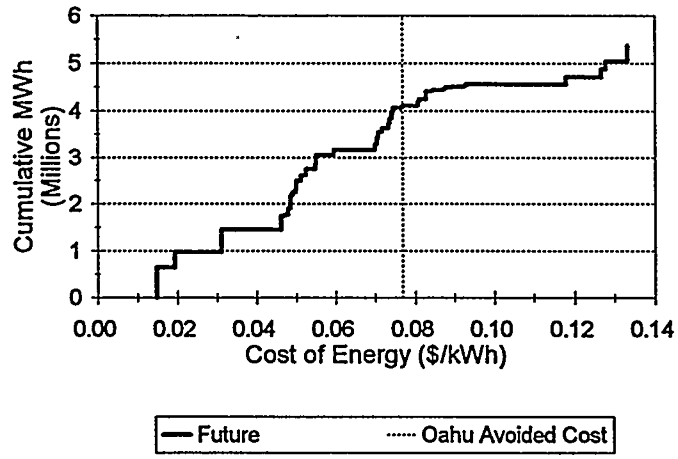
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Conservative	50	2	30	275,940	0.0627
Wind		Oahu	Kaena Point	Future	Incl	Conservative	15	1	30	26,560	0.0721
Wind		Oahu	Kahuku	Future	Incl	Conservative	30	1	30	47,716	0.0766
Wind		Oahu	Kahuku	Future	Incl	Conservative	50	1	30	79,208	0.0774
Wind		Oahu	Kaena Point	Future	Incl	Conservative	2	1	30	3,381	0.0797
Wind		Oahu	Kahuku	Future	Incl	Conservative	80	1	30	126,924	0.0845
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Conservative	50	1.5	30	76,454	0.0999
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Conservative	50	1.5	30	72,820	0.1019
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Conservative	50	3	30	94,924	0.1070
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Conservative	50	3	30	94,924	0.1077
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Conservative	50	3	30	94,924	0.1083
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Conservative	50	1.5	30	70,640	0.1126
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Conservative	50	3	30	84,754	0.1128
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Conservative	50	3	30	84,754	0.1135
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Conservative	50	3	30	84,754	0.1142
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Conservative	20	2	30	37,970	0.1181
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Conservative	20	2	30	33,901	0.1247
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Conservative	10	1	30	20,102	0.1265
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Conservative	10	1	30	18,985	0.1298
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Conservative	10	1	30	18,985	0.1345
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Conservative	10	1	30	16,951	0.1374
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Conservative	10	1	30	16,951	0.1420
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Conservative	10	1	30	16,951	0.1427
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Conservative	25	2	30	137,970	0.1521
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Conservative	80	1.5	30	137,620	0.1599
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Conservative	80	1.5	30	133,499	0.1721
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Conservative	80	1.5	30	144,487	0.1734
Wave		Oahu	Makapuu	Future	Incl	Conservative	60	2	30	105,316	0.2716
Wave		Oahu	Makapuu	Future	Incl	Conservative	30	2	30	52,663	0.2822
Wave		Oahu	Kahuku Point	Future	Incl	Conservative	60	2	30	98,372	0.2907
OTEC		Oahu	Kahe Point	Future	Incl	Conservative	60	2	30	270,789	0.2997
Wave		Oahu	Kahuku Point	Future	Incl	Conservative	30	2	30	49,188	0.3006
Wave		Oahu	NE Coast 2A	Future	Incl	Conservative	30	2	30	48,075	0.3078
Wave		Oahu	NE Coast 2C	Future	Incl	Conservative	30	2	30	45,998	0.3214
Wave		Oahu	Mokapu Point	Future	Incl	Conservative	30	2	30	45,087	0.3311
Wave		Oahu	Waimanalo Bay	Future	Incl	Conservative	30	2	30	39,939	0.3710

Island(s):	Oahu	Valuation:	Constant Dollars
Technology:	All Technologies	Financing:	Utility
Stage:	Future Technology	Tax Credits:	Included
Certainty:	Optimistic	Data:	All Data from Query
Trans. Cost:	Cost Included	Avoided Cost	$0.0770

RESOURCE SUPPLY CURVES



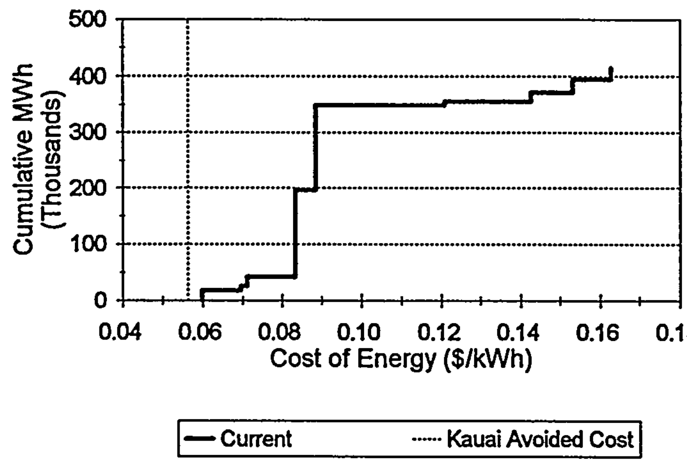
Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Optimistic	50	2	30	337,260	0.0194
Wave		Oahu	Makapuu	Future	Incl	Optimistic	60	2	30	279,377	0.0461
Wind		Oahu	Kaena Point	Future	Incl	Optimistic	15	1	30	36,966	0.0470
Wave		Oahu	Makapuu	Future	Incl	Optimistic	30	2	30	139,714	0.0478
Wave		Oahu	Kahuku Point	Future	Incl	Optimistic	60	2	30	265,253	0.0486
Wind		Oahu	Kahuku	Future	Incl	Optimistic	30	1	30	67,029	0.0491
Wind		Oahu	Kahuku	Future	Incl	Optimistic	50	1	30	111,268	0.0499
Wave		Oahu	Kahuku Point	Future	Incl	Optimistic	30	2	30	132,640	0.0499
Wind		Oahu	Kaena Point	Future	Incl	Optimistic	2	1	30	4,673	0.0505
Wave		Oahu	NE Coast 2A	Future	Incl	Optimistic	30	2	30	129,936	0.0511
Wave		Oahu	NE Coast 2C	Future	Incl	Optimistic	30	2	30	126,276	0.0525
Wave		Oahu	Mokapu Point	Future	Incl	Optimistic	30	2	30	122,913	0.0547
Wind		Oahu	Kahuku	Future	Incl	Optimistic	80	1	30	178,298	0.0550
Wave		Oahu	Waimanalo Bay	Future	Incl	Optimistic	30	2	30	111,677	0.0595
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Optimistic	50	3	30	128,426	0.0700
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Optimistic	50	3	30	128,426	0.0704
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Optimistic	50	3	30	128,426	0.0708
Solar Thermal	dish	Oahu	Pearl Harbor	Future	Incl	Optimistic	50	1.5	30	89,197	0.0719
Solar Thermal	dish	Oahu	Lualualei	Future	Incl	Optimistic	50	1.5	30	84,957	0.0735
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Optimistic	50	3	30	114,667	0.0737
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Optimistic	50	3	30	114,667	0.0741
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Optimistic	50	3	30	114,667	0.0746
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Optimistic	20	2	30	51,371	0.0769
Solar Thermal	dish	Oahu	N. Ewa Plain	Future	Incl	Optimistic	50	1.5	30	82,414	0.0808
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Optimistic	20	2	30	45,867	0.0811
Biomass Elec	grass crops	Oahu	Waialua	Future	Incl	Optimistic	25	2	30	168,630	0.0830
Photovoltaic	tracking	Oahu	Lualualei	Future	Incl	Optimistic	10	1	30	25,685	0.0843
Photovoltaic	tracking	Oahu	Pearl Harbor	Future	Incl	Optimistic	10	1	30	25,685	0.0873
Photovoltaic	tracking	Oahu	N. Ewa Plain	Future	Incl	Optimistic	10	1	30	25,685	0.0876
Photovoltaic	fixed	Oahu	Lualualei	Future	Incl	Optimistic	10	1	30	22,933	0.0891
Photovoltaic	fixed	Oahu	Pearl Harbor	Future	Incl	Optimistic	10	1	30	22,933	0.0924
Photovoltaic	fixed	Oahu	N. Ewa Plain	Future	Incl	Optimistic	10	1	30	22,933	0.0929
Solar Thermal	trough	Oahu	Lualualei	Future	Incl	Optimistic	80	1.5	30	160,556	0.1180
Solar Thermal	trough	Oahu	N. Ewa Plain	Future	Incl	Optimistic	80	1.5	30	155,749	0.1267
Solar Thermal	trough	Oahu	Pearl Harbor	Future	Incl	Optimistic	80	1.5	30	168,568	0.1278
OTEC		Oahu	Kahe Point	Future	Incl	Optimistic	60	2	30	335,543	0.1334

APPENDIX D

RESOURCE SUPPLY CURVES, ISLAND OF KAUAI

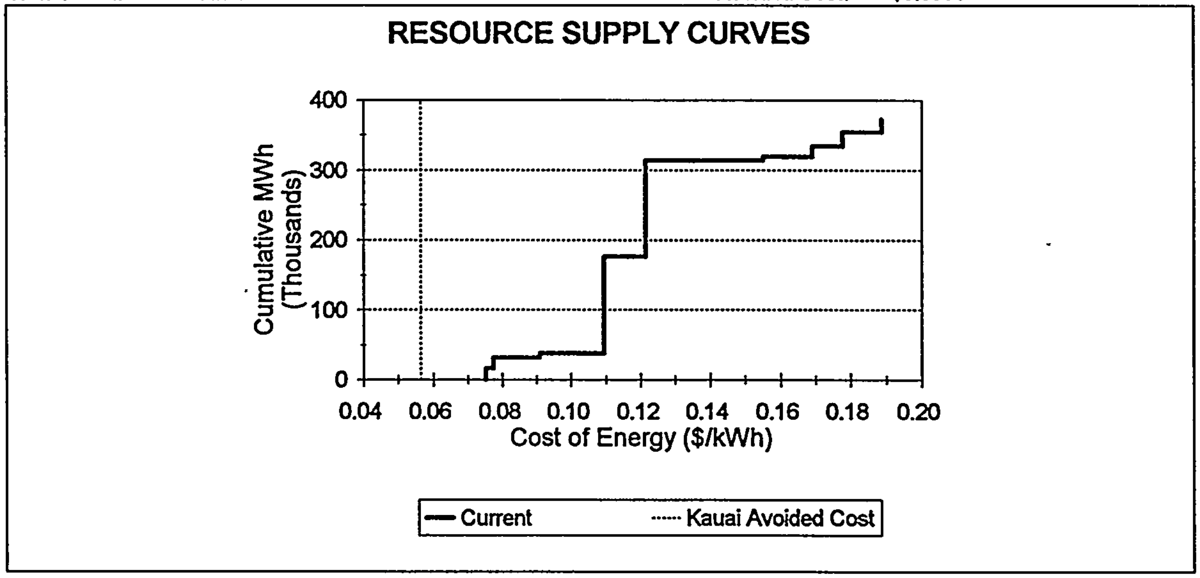
Island(s):	**Kauai**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Nominal**	**Tax Credits:**	**Included**
Stage:	**Current Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0564**

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Current	Incl	Nominal	10	1	30	18,252	0.0598
Wind		Kauai	Port Allen	Current	Incl	Nominal	5	1	30	7,763	0.0696
Hydro		Kauai	Wailua River	Current	Incl	Nominal	6.6	2	50	16,435	0.0712
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Nominal	25	2	30	153,300	0.0834
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Nominal	25	2	30	153,300	0.0886
Wind		Kauai	Anahola	Current	Incl	Nominal	7	1	30	6,651	0.1210
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Nominal	10	1.5	30	16,428	0.1427
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Nominal	10	2	30	22,159	0.1533
Photovoltaic	fixed	Kauai	Barking Sands	Current	Incl	Nominal	10	2	30	19,785	0.1629

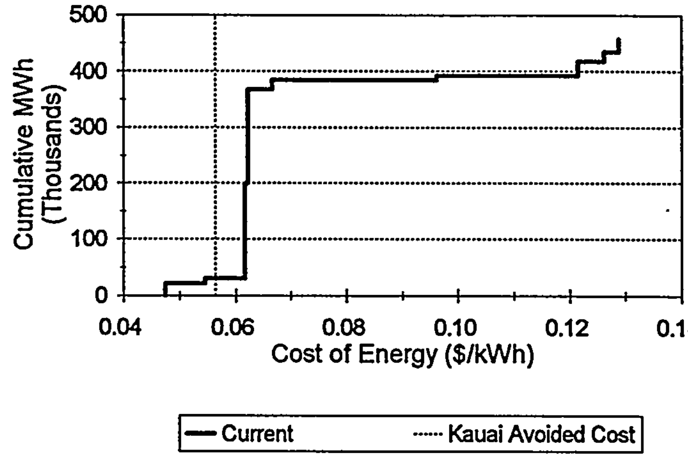
Island(s):	**Kauai**		**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**		**Financing:**	**Utility**
Certainty:	**Conservative**		**Tax Credits:**	**Included**
Stage:	**Current Technology**		**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**		**Avoided Cost:**	**$0.0564**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Hydro		Kauai	Wailua River	Current	Incl	Conservative	6.6	2	50	16,267	0.0753
Wind		Kauai	N. Hanapepe	Current	Incl	Conservative	10	1	30	15,430	0.0774
Wind		Kauai	Port Allen	Current	Incl	Conservative	5	1	30	6,519	0.0909
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Conservative	25	2	30	137,970	0.1094
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Conservative	25	2	30	137,970	0.1215
Wind		Kauai	Anahola	Current	Incl	Conservative	7	1	30	5,589	0.1552
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Conservative	10	1.5	30	14,786	0.1691
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Conservative	10	2	30	19,943	0.1777
Photovoltaic	fixed	Kauai	Barking Sands	Current	Incl	Conservative	10	2	30	17,806	0.1889

Island(s):	**Kauai**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Optimistic**	**Tax Credits:**	**Included**
Stage:	**Current Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0564**

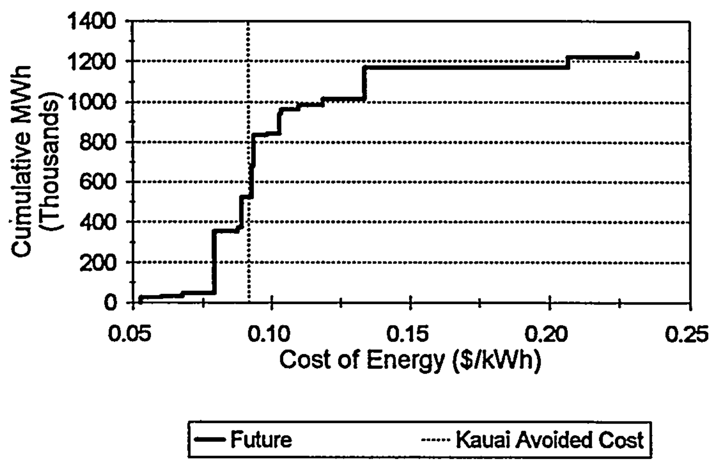
RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Current	Incl	Optimistic	10	1	30	21,296	0.0475
Wind		Kauai	Port Allen	Current	Incl	Optimistic	5	1	30	9,111	0.0546
Biomass Elec	tree crops	Kauai	Kaumakani	Current	Incl	Optimistic	25	2	30	168,630	0.0617
Biomass Elec	tree crops	Kauai	Lihue	Current	Incl	Optimistic	25	2	30	168,630	0.0622
Hydro		Kauai	Wailua River	Current	Incl	Optimistic	6.6	2	50	16,770	0.0667
Wind		Kauai	Anahola	Current	Incl	Optimistic	7	1	30	7,800	0.0963
Photovoltaic	tracking	Kauai	Barking Sands	Current	Incl	Optimistic	10	2	30	25,483	0.1215
Solar Thermal	dish	Kauai	Barking Sands	Current	Incl	Optimistic	10	1.5	30	17,250	0.1262
Photovoltaic	fixed	Kauai	Barking Sands	Current	Incl	Optimistic	10	2	30	22,752	0.1290

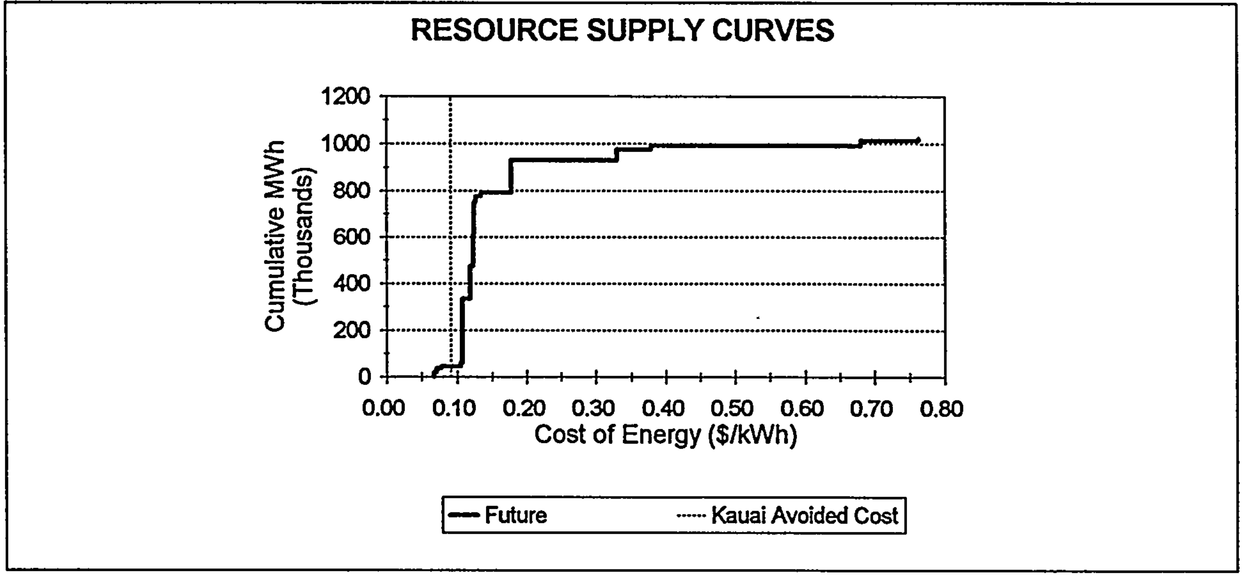
Island(s):	Kauai	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	All Data from Query
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0919

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Future	Incl	Nominal	10	1	30	22,602	0.0529
Wind		Kauai	Port Allen	Future	Incl	Nominal	5	1	30	9,321	0.0603
Hydro		Kauai	Wailua River	Future	Incl	Nominal	6.6	2	50	16,435	0.0678
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Nominal	50	2	30	306,600	0.0794
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Nominal	10	1.5	30	17,250	0.0878
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Nominal	25	2	30	153,300	0.0894
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Nominal	25	2	30	153,300	0.0929
Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Nominal	25	2	30	153,300	0.0937
Wind		Kauai	Anahola	Future	Incl	Nominal	7	1	30	8,200	0.0984
Wave		Kauai	Anahola	Future	Incl	Nominal	30	2	30	98,947	0.1030
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Nominal	10	1	30	22,962	0.1037
Photovoltaic	fixed	Kauai	Barking Sands	Future	Incl	Nominal	10	1	30	20,502	0.1099
Wave		Kauai	Anahola	Future	Incl	Nominal	10	2	30	32,972	0.1189
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Nominal	25	2	30	153,300	0.1336
Wave		Kauai	Barking Sands	Future	Incl	Nominal	30	2	30	51,793	0.2072
Wave		Kauai	Barking Sands	Future	Incl	Nominal	10	2	30	17,261	0.2316

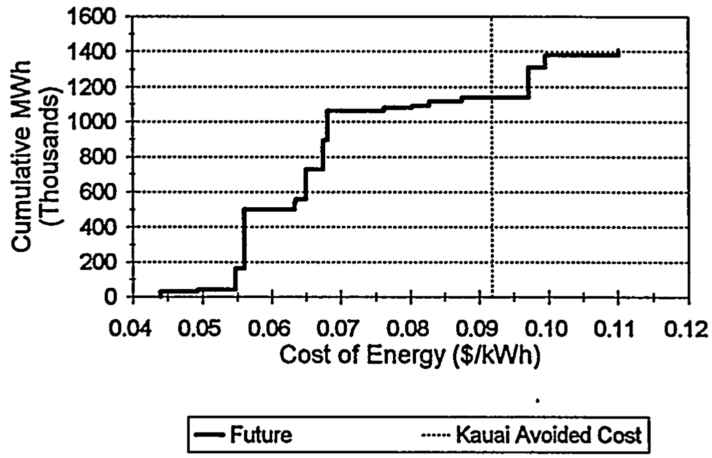
Island(s):	**Kauai**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Conservative**	**Tax Credits:**	**Included**
Stage:	**Future Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0919**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Future	Incl	Conservative	10	1	30	19,107	0.0673
Hydro		Kauai	Wailua River	Future	Incl	Conservative	6.6	2	50	16,267	0.0717
Wind		Kauai	Port Allen	Future	Incl	Conservative	5	1	30	7,828	0.0780
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Conservative	10	1.5	30	15,525	0.1058
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Conservative	50	2	30	275,940	0.1078
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Conservative	25	2	30	137,970	0.1191
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Conservative	25	2	30	137,970	0.1238
Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Conservative	25	2	30	137,970	0.1249
Wind		Kauai	Anahola	Future	Incl	Conservative	7	1	30	6,891	0.1264
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Conservative	10	1	30	19,518	0.1275
Photovoltaic	fixed	Kauai	Barking Sands	Future	Incl	Conservative	10	1	30	17,427	0.1350
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Conservative	25	2	30	137,970	0.1781
Wave		Kauai	Anahola	Future	Incl	Conservative	30	2	30	45,353	0.3301
Wave		Kauai	Anahola	Future	Incl	Conservative	10	2	30	15,115	0.3792
Wave		Kauai	Barking Sands	Future	Incl	Conservative	30	2	30	23,201	0.6812
Wave		Kauai	Barking Sands	Future	Incl	Conservative	10	2	30	7,733	0.7639

Island(s):	**Kauai**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Optimistic**	**Tax Credits:**	**Included**
Stage:	**Future Technology**	**Data:**	**All Data from Query**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0919**

RESOURCE SUPPLY CURVES



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	Lead	Life	MWh	COE
Wind		Kauai	N. Hanapepe	Future	Incl	Optimistic	10	1	30	26,372	0.0440
Wind		Kauai	Port Allen	Future	Incl	Optimistic	5	1	30	10,940	0.0494
Wave		Kauai	Anahola	Future	Incl	Optimistic	30	2	30	124,296	0.0548
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Optimistic	50	2	30	337,260	0.0561
Wave		Kauai	Anahola	Future	Incl	Optimistic	10	2	30	41,417	0.0634
Hydro		Kauai	Wailua River	Future	Incl	Optimistic	6.6	2	50	16,770	0.0635
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Optimistic	25	2	30	168,630	0.0650
Biomass Elec	grass crops	Kauai	Kaumakani	Future	Incl	Optimistic	25	2	30	168,630	0.0675
Biomass Elec	tree crops	Kauai	Kaumakani	Future	Incl	Optimistic	25	2	30	168,630	0.0681
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Optimistic	10	1.5	30	18,112	0.0762
Wind		Kauai	Anahola	Future	Incl	Optimistic	7	1	30	9,618	0.0803
Photovoltaic	tracking	Kauai	Barking Sands	Future	Incl	Optimistic	10	1	30	26,407	0.0828
Photovoltaic	fixed	Kauai	Barking Sands	Future	Incl	Optimistic	10	1	30	23,577	0.0876
Biomass Elec	grass crops	Kauai	Lihue	Future	Incl	Optimistic	25	2	30	168,630	0.0972
Wave		Kauai	Barking Sands	Future	Incl	Optimistic	30	2	30	71,415	0.0996
Wave		Kauai	Barking Sands	Future	Incl	Optimistic	10	2	30	23,800	0.1102

APPENDIX E

TIME-OF-DAY PRICING SUMMARIES

Energy Payment Comparison - Island of Hawaii

			Project	Payment - 2005		Daily	Annual Sales		Time of Day
			Capacity	Average	Time of Day	Energy	Based on	Based on	Pricing
Technology	Type	Location	(MW)	($/kWh)	($/kWh)	(MWh)	Average	Time of Day	Advantage
Photovoltaic	tracking	Keahole	30	$0.0906	$0.0972	225.9	$7,470,642	$8,013,100	$542,458
Photovoltaic	fixed	Keahole	30	$0.0906	$0.0973	182.3	$6,028,753	$6,475,856	$447,102
Photovoltaic	tracking	Keahole	50	$0.0906	$0.0972	376.5	$12,451,070	$13,355,167	$904,096
Photovoltaic	fixed	Keahole	50	$0.0906	$0.0973	303.8	$10,047,922	$10,793,093	$745,170
Photovoltaic	tracking	N. Kohala	5	$0.0906	$0.0973	34.3	$1,133,429	$1,217,003	$83,574
Photovoltaic	fixed	N. Kohala	5	$0.0906	$0.0973	29.0	$957,843	$1,028,803	$70,959
Photovoltaic	tracking	N. Kohala	15	$0.0906	$0.0973	102.8	$3,400,287	$3,651,010	$250,723
Photovoltaic	fixed	N. Kohala	15	$0.0906	$0.0973	86.9	$2,873,530	$3,086,409	$212,878
Photovoltaic	tracking	Waikoloa	30	$0.0906	$0.0972	225.9	$7,470,642	$8,013,100	$542,458
Photovoltaic	fixed	Waikoloa	30	$0.0906	$0.0973	182.3	$6,028,753	$6,475,856	$447,102
Photovoltaic	tracking	Waikoloa	50	$0.0906	$0.0972	376.5	$12,451,070	$13,355,167	$904,096
Photovoltaic	fixed	Waikoloa	50	$0.0906	$0.0973	303.8	$10,047,922	$10,793,093	$745,170
Solar Thermal	dish	Keahole	30	$0.0906	$0.0973	150.8	$4,986,958	$5,356,638	$369,679
Solar Thermal	trough	Keahole	30	$0.0906	$0.0973	176.4	$5,834,752	$6,268,308	$433,555
Solar Thermal	dish	N. Kohala	5	$0.0906	$0.0973	27.1	$896,725	$963,380	$66,655
Solar Thermal	dish	N. Kohala	15	$0.0906	$0.0973	80.5	$2,663,183	$2,861,142	$197,959
Solar Thermal	dish	Waikoloa	30	$0.0906	$0.0973	146.9	$4,857,058	$5,217,107	$360,050
Solar Thermal	trough	Waikoloa	30	$0.0906	$0.0973	171.8	$5,682,385	$6,104,619	$422,234
Wave		Honokaa 2A	10	$0.0906	$0.0905	92.0	$3,043,067	$3,041,298	($1,769)
Wave		N. Kohala	10	$0.0906	$0.0905	84.9	$2,808,491	$2,806,858	($1,633)
Wave		N. Kohala	30	$0.0906	$0.0905	254.8	$8,427,373	$8,422,474	($4,900)
Wave		Pepeekeo 2E	10	$0.0906	$0.0905	88.7	$2,932,343	$2,930,638	($1,705)
Wind		Kahua Ranch	5	$0.0906	$0.0906	35.0	$1,155,848	$1,155,855	$7
Wind		Kahua Ranch	15	$0.0906	$0.0906	105.2	$3,478,068	$3,478,090	$22
Wind		Lalamilo Wells	3	$0.0906	$0.0908	35.4	$1,171,988	$1,173,940	$1,952
Wind		Lalamilo Wells	30	$0.0906	$0.0908	316.6	$10,469,370	$10,486,808	$17,438
Wind		Lalamilo Wells	50	$0.0906	$0.0908	525.5	$17,379,153	$17,408,101	$28,948
Wind		N. Kohala	5	$0.0906	$0.0915	61.0	$2,016,019	$2,036,235	$20,217
Wind		N. Kohala	15	$0.0906	$0.0915	194.8	$6,440,754	$6,505,343	$64,589

Energy Payment Comparison - Island of Maui

Technology	Type	Location	Project Capacity (MW)	Payment - 2005 Average ($/kWh)	Payment - 2005 Time of Day ($/kWh)	Daily Energy (MWh)	Annual Sales Based on Average	Annual Sales Based on Time of Day	Time of Day Pricing Advantage
Photovoltaic	tracking	Kahului	10	0.0984	0.1012	70.5	$2,531,644	$2,605,644	$74,000
Photovoltaic	fixed	Kahului	10	0.0984	0.1013	58.2	$2,090,056	$2,151,903	$61,846
Photovoltaic	tracking	Kahului	30	0.0984	0.1012	211.5	$7,594,931	$7,816,931	$222,000
Photovoltaic	fixed	Kahului	30	0.0984	0.1013	174.6	$6,270,169	$6,455,708	$185,539
Photovoltaic	tracking	Kihei	10	0.0984	0.1012	71.1	$2,554,129	$2,628,180	$74,051
Photovoltaic	fixed	Kihei	10	0.0984	0.1013	58.0	$2,082,663	$2,144,227	$61,563
Photovoltaic	tracking	Kihei	30	0.0984	0.1012	213.4	$7,662,386	$7,884,540	$222,153
Photovoltaic	fixed	Kihei	30	0.0984	0.1013	174.0	$6,247,989	$6,432,680	$184,690
Photovoltaic	tracking	Puunene	10	0.0984	0.1012	70.5	$2,531,644	$2,605,644	$74,000
Photovoltaic	fixed	Puunene	10	0.0984	0.1013	58.2	$2,090,056	$2,151,903	$61,846
Photovoltaic	tracking	Puunene	30	0.0984	0.1012	211.5	$7,594,931	$7,816,931	$222,000
Photovoltaic	fixed	Puunene	30	0.0984	0.1013	174.6	$6,270,169	$6,455,708	$185,539
Solar Thermal	dish	Kahului	10	0.0984	0.1013	43.6	$1,567,176	$1,613,663	$46,487
Solar Thermal	dish	Kahului	30	0.0984	0.1013	129.6	$4,654,331	$4,792,391	$138,060
Solar Thermal	trough	Kahului	30	0.0984	0.1013	151.6	$5,444,627	$5,606,153	$161,526
Solar Thermal	dish	Kihei	10	0.0984	0.1013	46.3	$1,664,050	$1,713,389	$49,339
Solar Thermal	dish	Kihei	30	0.0984	0.1013	137.6	$4,941,931	$5,088,458	$146,527
Solar Thermal	trough	Kihei	30	0.0984	0.1013	161.0	$5,780,297	$5,951,781	$171,484
Solar Thermal	dish	Puunene	10	0.0984	0.1013	45.0	$1,615,555	$1,663,476	$47,922
Solar Thermal	dish	Puunene	30	0.0984	0.1013	133.6	$4,797,715	$4,940,028	$142,313
Solar Thermal	trough	Puunene	30	0.0984	0.1013	156.3	$5,613,042	$5,779,565	$166,522
Wave		Lower Paia	10	0.0984	0.0983	93.0	$3,340,807	$3,340,032	($775)
Wave		Lower Paia	30	0.0984	0.0983	279.2	$10,026,058	$10,023,732	($2,327)
Wave		Lower Paia	60	0.0984	0.0983	558.4	$20,049,954	$20,045,301	($4,653)
Wave		Opana Point	10	0.0984	0.0983	96.7	$3,471,935	$3,471,129	($806)
Wave		Opana Point	30	0.0984	0.0983	290.2	$10,419,835	$10,417,417	($2,418)
Wave		Opana Point	60	0.0984	0.0983	580.4	$20,837,310	$20,832,475	($4,835)
Wave		Waiehu Pt.	10	0.0984	0.0983	92.4	$3,315,840	$3,315,070	($769)
Wave		Waiehu Pt.	30	0.0984	0.0983	277.2	$9,953,122	$9,950,813	($2,310)
Wind		McGregor Point	10	0.0984	0.0998	67.3	$2,415,326	$2,449,470	$34,144
Wind		NW Haleakala	10	0.0984	0.0998	58.0	$2,080,853	$2,111,792	$30,939
Wind		NW Haleakala	30	0.0984	0.0998	153.5	$5,509,761	$5,591,682	$81,922
Wind		NW Haleakala	50	0.0984	0.0998	254.7	$9,146,203	$9,282,193	$135,990
Wind		Puunene	10	0.0984	0.0998	43.1	$1,547,524	$1,569,465	$21,941
Wind		Puunene	30	0.0984	0.0998	123.2	$4,425,185	$4,487,926	$62,741
Wind		West Maui	10	0.0984	0.0985	52.6	$1,889,824	$1,892,648	$2,824
Wind		West Maui	30	0.0984	0.0985	159.5	$5,726,740	$5,735,298	$8,559
Wind		West Maui	50	0.0984	0.0985	264.8	$9,506,388	$9,520,595	$14,208

Energy Payment Comparison - Island of Oahu

Technology	Type	Location	Project Capacity (MW)	Payment - 2005 Average ($/kWh)	Payment - 2005 Time of Day ($/kWh)	Daily Energy (MWh)	Annual Sales Based on Average	Annual Sales Based on Time of Day	Time of Day Pricing Advantage
Photovoltaic	tracking	Lualualei	10	$0.0770	$0.0845	65.7	$1,848,388	$2,028,398	$180,010
Photovoltaic	fixed	Lualualei	10	$0.0770	$0.0846	54.6	$1,535,656	$1,685,984	$150,328
Photovoltaic	tracking	Lualualei	20	$0.0770	$0.0845	131.5	$3,696,776	$4,056,797	$360,020
Photovoltaic	fixed	Lualualei	20	$0.0770	$0.0846	109.2	$3,071,313	$3,371,968	$300,655
Photovoltaic	tracking	Lualualei	50	$0.0770	$0.0845	328.7	$9,241,940	$10,141,992	$900,051
Photovoltaic	fixed	Lualualei	50	$0.0770	$0.0846	273.1	$7,678,282	$8,429,919	$751,638
Photovoltaic	tracking	N. Ewa Plain	10	$0.0770	$0.0845	65.7	$1,848,388	$2,028,398	$180,010
Photovoltaic	fixed	N. Ewa Plain	10	$0.0770	$0.0846	54.6	$1,535,656	$1,685,984	$150,328
Photovoltaic	tracking	N. Ewa Plain	50	$0.0770	$0.0845	328.7	$9,241,940	$10,141,992	$900,051
Photovoltaic	fixed	N. Ewa Plain	50	$0.0770	$0.0846	273.1	$7,678,282	$8,429,919	$751,638
Photovoltaic	tracking	Pearl Harbor	10	$0.0770	$0.0845	65.7	$1,848,388	$2,028,398	$180,010
Photovoltaic	fixed	Pearl Harbor	10	$0.0770	$0.0846	54.6	$1,535,656	$1,685,984	$150,328
Photovoltaic	tracking	Pearl Harbor	50	$0.0770	$0.0845	328.7	$9,241,940	$10,141,992	$900,051
Photovoltaic	fixed	Pearl Harbor	50	$0.0770	$0.0846	273.1	$7,678,282	$8,429,919	$751,638
Solar Thermal	dish	Lualualei	50	$0.0770	$0.0846	221.6	$6,231,028	$6,842,393	$611,365
Solar Thermal	trough	Lualualei	80	$0.0770	$0.0846	418.8	$11,774,247	$12,929,492	$1,155,245
Solar Thermal	dish	N. Ewa Plain	50	$0.0770	$0.0846	215.0	$6,044,432	$6,637,490	$593,057
Solar Thermal	trough	N. Ewa Plain	80	$0.0770	$0.0846	406.3	$11,421,738	$12,542,396	$1,120,658
Solar Thermal	dish	Pearl Harbor	50	$0.0770	$0.0846	232.7	$6,541,361	$7,183,175	$641,814
Solar Thermal	trough	Pearl Harbor	80	$0.0770	$0.0846	439.7	$12,360,730	$13,573,518	$1,212,789
Wave		Kahuku Pt.	30	$0.0770	$0.0770	289.1	$8,128,786	$8,122,547	($6,239)
Wave		Kahuku Pt.	60	$0.0770	$0.0770	578.2	$16,256,109	$16,243,633	($12,476)
Wave		Makapuu	30	$0.0770	$0.0770	307.2	$8,636,797	$8,630,168	($6,628)
Wave		Makapuu	60	$0.0770	$0.0770	614.3	$17,270,668	$17,257,414	($13,255)
Wave		Makapu Pt.	30	$0.0770	$0.0770	268.2	$7,540,571	$7,534,784	($5,787)
Wave		NE Coast 2A	30	$0.0770	$0.0770	283.9	$7,982,233	$7,976,107	($6,126)
Wave		NE Coast 2C	30	$0.0770	$0.0770	278.8	$7,838,065	$7,832,050	($6,015)
Wave		Waimanalo Bay	30	$0.0770	$0.0770	243.5	$6,847,137	$6,841,882	($5,255)
Wind		Kaena Point	2	$0.0770	$0.0793	10.9	$307,419	$316,516	$9,097
Wind		Kaena Point	15	$0.0770	$0.0793	86.2	$2,423,518	$2,495,237	$71,719
Wind		Kahuku	30	$0.0770	$0.0782	155.2	$4,362,192	$4,428,411	$66,218
Wind		Kahuku	50	$0.0770	$0.0782	257.6	$7,241,240	$7,351,162	$109,922
Wind		Kahuku	80	$0.0770	$0.0782	412.7	$11,603,432	$11,779,572	$176,140

Energy Payment Comparison - Island of Kauai

			Project	Payment - 2005		Daily	Annual Sales		Time of Day
			Capacity	Average	Time of Day	Energy	Based on	Based on	Pricing
Technology	Type	Location	(MW)	($/kWh)	($/kWh)	(MWh)	Average	Time of Day	Advantage
Photovoltaic	tracking	Barking Sands	10	$0.0919	$0.0928	69.0	$2,312,735	$2,337,075	$24,340
Photovoltaic	fixed	Barking Sands	10	$0.0919	$0.0928	56.1	$1,882,487	$1,902,388	$19,901
Solar Thermal	dish	Barking Sands	10	$0.0919	$0.0928	47.2	$1,581,112	$1,597,853	$16,741
Wave		Anahola	10	$0.0919	$0.0919	90.3	$3,027,038	$3,026,788	($251)
Wave		Anahola	30	$0.0919	$0.0919	270.9	$9,083,961	$9,083,209	($752)
Wave		Barking Sands	10	$0.0919	$0.0919	47.3	$1,584,669	$1,584,538	($131)
Wave		Barking Sands	30	$0.0919	$0.0919	141.8	$4,754,925	$4,754,532	($394)
Wind		Anahola	7	$0.0919	$0.0920	22.4	$751,947	$752,908	$961
Wind		N. Hanapepe	10	$0.0919	$0.0919	61.8	$2,071,519	$2,071,464	($55)
Wind		Port Allen	5	$0.0919	$0.0923	27.1	$910,300	$914,616	$4,316

APPENDIX F

CASE STUDIES FOR SMALL-SCALE APPLICATIONS

Photovoltaics in Dispersed Utility Applications
Photovoltaics in Off-Grid Applications
Small-Scale Wind-Electric Applications
Domestic Solar Water Heating
Solar Desalination/Distillation
Solar Thermal Industrial Heat
Ocean Thermal Resource Applications

PHOTOVOLTAICS IN DISPERSED UTILITY APPLICATIONS

Photovoltaic (PV) technology can be used by utilities to reduce their peak demand during certain hours or times of year, or to defer the costs associated with transmission line upgrades in areas where the power transmission lines are near capacity and slow steady load growth is expected. In either case, the system consists of PV panels, storage batteries, and power inverters connected to the utility power system.

To reduce peak power demand, PV technology can be used as a demand side measure. On a residential scale this can be accomplished without the need for battery storage by utilizing PV generated power on an as-available basis on the customer's side of the utility meter. The customer realizes a benefit through reduced electricity usage and in areas where the daily peak demand corresponds well with PV output the utility benefits through a reduction in the peak system load. With consumer owned systems the investment can be reduced according to State and Federal tax credits, and implementation can be encouraged through utility participation up to the value of the load reduction evaluated by the utility.

In commercial sized systems, battery capacity and controls can be included to reduce the utility peak load as well as the customer's demand charge. The PV panels are used to charge a battery bank, when the battery is full, the system operates much like the residential measure described above. Using the control system, the battery can be made to discharge supplemented by the available power from the PV panels to achieve as much as 150% of the PV rated capacity. The customer can choose the time of day at which the discharge will occur according to their usage or may even contract with the utility for power delivery during certain times of the year. Reducing demand charges can have a significant impact on utility bills, and the power on demand provides additional security for the utility.

Other US utilities have also shown that larger PV/battery systems can be used to support existing utility power distribution networks. Such systems have been evaluated to recognize their value to the utility in terms of their capacity value, energy value, deferral of distribution upgrades, reduction of system losses, increased reliability, and others. Locations where these types of projects can be favorably implemented would normally exhibit one or more of the following characteristics: planned transmission and distribution investments, small substations, summer peaking loads, slow feeder load growth, and available and inexpensive land.

COST AND PERFORMANCE

Criteria	*PV-DSM Residential*	*PV-DSM Commercial*	*Utility Grid Support*
Capital Cost ($/kW):			
1995	6,000 - 7,000	7,800	5,200 - 6,500
2005	3,500 - 4,500	5,650	3,200 - 4,000
Operating Cost:			
fixed ($/kW-yr)	15.00 - 19.20	15.00 - 19.20	2.50 - 4.00
variable ($/MWh)	2.00 - 3.00	2.00 - 3.00	1.00 - 1.50
Capacity Factor:	20 - 25%	20 - 25%	25 - 26%

REFERENCES

1. *Grid Support Photovoltaics: Summary of Case Studies*, Freeman, Sullivan & Co. August 25, 1994.
2. *The Value of Distributed PV Systems in Today's Electric Utilities*, Bigger, J. and W., Solar Industry Journal. Third Quarter 1992.

3. *Commercial Building Demand Side Management Tools: Requirements for Dispachable Photovoltaic Systems*, Byrne, J. et al., Proceedings of the 23rd IEE PV Specialist Conference in Louisville, Kentucky. May 1993.
4. *PV DSM as a Green Investment Strategy*, Byrne, J. et al., Proceedings of the 5th National Conference on Integrated Resource Planning. May 1994.
5. Pacific Energy Group.

PHOTOVOLTAICS IN OFF-GRID APPLICATIONS

Photovoltaics (PV) are often used for applications where utility power access is not available and low service requirements are highly desirable such as remote residences, radio repeater stations, or highway sign lighting. The systems consist of PV panels, batteries, wiring, and varying degrees of monitoring and safety devices. There are no moving parts and very little maintenance is required.

The first step in sizing a residential system generally begins with reducing the demand through conservation measures or identifying alternative sources for the desired service. This most important step greatly reduces the cost of the PV system. The number of PV panels required and the size of the battery bank are directly related to the anticipated energy requirement.

Usually PV applications are compared against other methods of remote power (such as diesel-generator sets) or utility power line extensions. In fact, several utilities in the US have programs for providing utility power to remote residences with photovoltaic power systems when doing so is determined to be more cost effective than a line extension. State and Federal Tax Credits are applicable for certain ownership/application combinations.

COST AND PERFORMANCE

Criteria	*Value*
Capital Cost:	
PV Panels ($/watt)	6.00
Batteries ($/amp-hour; 12 V)	1.00
Wiring & Other Equipment	20% of above
Replacement Batteries every 4-8 years ($/amp-hour; 12 V)	1.00
Operating Cost:	minimal

REFERENCES

1. *Evaluating Photovoltaic Applications - A Guide for Utilities*. Stevens, J. et al., Sandia National Laboratories. 1990.

SMALL SCALE WIND-ELECTRIC APPLICATIONS

Small wind turbines can be used for a variety of applications involving electrical uses such as water pumping and battery charging. Models are available in a number of different configurations and sizes ranging from very small up to 7 meters in rotor diameter. Systems would always include a wind turbine and tower, a control device, as well as the necessary wiring and safety equipment and may include batteries, inverters, pumps, or other end use equipment.

In the very smallest of systems (used for marine applications), the tower may take the form of a firmly fixed post, but small wind turbine towers are more commonly found as guyed poles, or free-standing truss towers.

Examples of small scale wind-electric applications include water pumping for irrigation, drinking water, or aquaculture, and battery charging for cathodic protection, remote residences, and communication equipment. While cost and performance will vary widely depending on the application, and system size, typical values are given in the table below.

COST AND PERFORMANCE

Criteria	*Stand-Alone Wind Electric*	*Wind Electric Water Pumping*
Capital Cost ($/kW):	3,000 - 4,000	3,500 - 7,500
Replacement Costs ($/kW, every 4-8 yrs)	800 - 1,400	250 - 500
Operating Cost ($/yr):	50 - 125	50 - 125
Performance:	20 - 40% Capacity Factor	10 - 25 m^3/kw-day*

* average daily water delivery assuming 20m total dynamic head and 5.5 m/s average wind speed

REFERENCES

1. *Wind Power for Home and Business: Renewable Energy for the 1990s and Beyond*, Gipe, P. 1993.

DOMESTIC SOLAR WATER HEATING

Solar domestic hot water heaters are common throughout the state. The solar hot water heating system consists of a solar collector, a storage tank, a thermostat, and electric heating coils for back-up power. Various state and federal tax credits are available for solar hot water heaters depending on whether the unit is for a single family residence, multiple unit building, or for a commercial building. The initial cost of a solar hot water heater is high when compared to a traditional electric hot water heater.

One measure that has been used by other US utilities to promote solar hot water heating as a demand side measure is to provide financing up to a fixed total amount per unit that would allow the customer a combination of energy and loan payments that are lower than their current water heating costs. This kind of a measure not only eases the customer's cost, and provides the utility with a cost effective demand-side management measure, but provides a control mechanism on the market price of solar hot water heaters.

Of course, the solar water heater only provides savings to the customer and the utility if it continues to function properly. A low cost inspection and maintenance program would ensure satisfactory results for both the utility and its customers.

COST AND PERFORMANCE

Criteria	*Value*
Capital Cost ($):	3,500 - 4,000
Operating Cost ($/yr):	30 - 50
Energy Savings (kWh/yr):	3,400 - 3,600

REFERENCES

1. Cliff Murley, Sacramento Municipal Utility District, Solar Water Heating Programs.
2. Pacific Energy Group.

SOLAR DESALINATION / DISTILLATION

Depending on the amount of pure water desired, there are a variety of renewable energy technologies that can be used. For very small water demands the simplest is direct solar distillation of water. Larger centralized systems may use direct solar techniques, reverse osmosis using electrical power input from renewable energy sources, or may stand alone as in the case of an ocean thermal energy conversion facility operated to produce fresh water

Cost and performance information is given below for one small scale system (residential drinking water) utilizing a simple and proven technology that could be implemented with no additional load to the electric utility system.

COST AND PERFORMANCE

Criteria	*Solar Distillation*
Capital Cost ($):	350.00
Operating Cost:	
fixed ($/yr)	minimal
variable ($/gal)	minimal
Performance (gal/yr):	730

REFERENCES

1. McCracken Solar Company, Alturas, California.

SOLAR THERMAL INDUSTRIAL HEAT

Among a variety of methods for converting solar energy to useful heat, solar thermal parabolic troughs can supply heat at temperatures of 100 - 350°C for a variety of industrial processes such as food processing, although current utilization of this technology is not widespread. The system consists of reflective parabolic troughs which track the path of the sun and concentrate the rays on a working fluid in an insulated collector tube, and heat exchangers to transfer the heat to the industrial process system as required. Depending on the application, a backup source of heat may also be utilized.

Current heating applications are more likely to be cogeneration or fuel based, so rather than displacing electricity, solar industrial heat systems would offset fuel consumption. Solar thermal industrial heat systems have been shown to be cost effective when compared to mainland uses of natural gas, and may be even more competitive with alternatives in Hawaii.

COST AND PERFORMANCE

Criteria	*Current*	*Future*
Capital Cost ($\$/m^2$):	237	250
Operating Cost ($\$/m^2/yr$):	2.40	2.4
Replacement Costs ($\$/m^2$, every 5 yrs):	21.00	21.00
Energy Savings ($MBTU/m^2/yr$):	2.20 - 2.75	3.60 - 4.30

REFERENCES

1. *Economic Status and Prospects of Solar Thermal Industrial Heat*, Williams, T. and M. Hale, National Renewable Energy Laboratory. December 1992.

ALTERNATIVE OCEAN THERMAL RESOURCE APPLICATIONS

DESALINATION

In the open-cycle OTEC process, a small fraction of the warm water stream is vaporized or "flashed" under a partial vacuum. Flow of this water vapor towards the condenser is used to drive a low-pressure steam turbine. After exiting the turbine, the water vapor is condensed in a thin-walled plate heat exchanger by cold deep ocean water, and the condensate is collected as marketable fresh water. Cost and performance data for an open-cycle OTEC plant optimized for fresh water production are based on a 1992 paper by Luis Vega of the Pacific International Center for High Technology Research (PICHTR; Reference 1). This is a land-based plant with two condenser stages, having a net power output of 9 MWe and a fresh water production capacity of 35,000 m³/day. Cost and performance data are summarized in Table 1. Also presented in Table 1 are similar data for a conventional desalination plant using reverse osmosis (RO) technology. These data are base on a 1991 paper by Gordon Leitner (Reference 2), which describes the Las Palmas III RO plant in the Canary Islands.

Table 1. Desalination Cost and Performance Data

Characteristic	Open-cycle OTEC	Conventional RO
Project location	unspecified site with $\Delta T = 20°C$	Las Palmas, Canary Islands
Fresh water production capacity	35,000 m^3/day	36,000 m^3/day
Capital cost	$132,300,000	$55,000,000
Non-energy O&M cost	$1,984,500	$1,988,000
Energy consumption per unit output	none	5.8 kWh/m^3
Energy production per unit output	6.0 kWh/m^3	none
Annual fresh water output	10,500,000 m^3	10,200,000 m^3
Annual energy consumption	none	59,200 MWh
Annual energy production	63,000 MWh	none

Based on the data in Table 1, the levelized cost of energy (in constant dollars) at which fresh water from the open-cycle OTEC plant becomes economically competitive with that produced by a conventional reverse osmosis (RO) plant is estimated to be 6.5¢/kWh. This assumes a 20-year service life and 80% utilization factor for both plants, with all financial parameters the same as those used for utility financing of the electric power generating projects in the main body of the report.

DISTRICT COOLING

Deep cold ocean water can be used to provide district cooling for commercial building developments. The ocean water is passed through a heat exchanger, chilling fresh water on the other side of the heat exchanger plates. The deep naturally cold ocean water replaces conventional refrigeration equipment, which has much higher peak power and contributes substantially to the evening peak in the daily utility load profile. The deep seawater pumps have a much lower energy requirement and represent a continual rather than peaked load.

Cost and performance data for deep seawater and conventional district cooling systems are presented in Table 2, taken from a 1994 report prepared by Makai Ocean Engineering for the State of Hawaii (Reference 3). Data are presented for two system cooling loads: 2,500 tons and 5,300 tons (note that one ton of cooling represents a heat removal rate of 200 BTU per minute of 0.288 MBTU/day).

Table 2. District Cooling Cost and Performance Data

Cooling Load	**2,500 tons**		**5,300 tons**	
Technology	Deep SW	Conventional	Deep SW	Conventional
Capital cost	$10,577,000	$4,688,000	$16,253,000	$9,938,000
Non-energy O&M cost	$477,400	$395,000	$786,300	$879,000
Unit energy consumption	12.3 kWh per MBTU	70.8 kWh per MBTU	14.8 kWh per MBTU	70.8 kWh per MBTU
Total annual heat removed	157,680 MBTU	157,680 MBTU	334,280 MBTU	334,280 MBTU
Annual energy consumption	1,940 MWh	11,160 MWh	4,950 MWh	23,670 MWh

Based on the data in Table 2, the levelized cost of energy (in constant dollars) at which deep sea water district cooling becomes economically competitive with a conventional chiller system is estimated to be 7.9¢/kWh for the 2,500-ton load and 3.2 ¢/kWh for the 5,300-ton load. This assumes a 20-year service life and 60% utilization factor for both types of district cooling, with all financial parameters the same as those used for utility financing of the electric power generating projects in the main body of the report.

There are three potential locations for deep seawater district cooling projects in Hawaii: two larger systems (each approximately 10,000 tons) at West Beach, Oahu, and Kailua-Kona on the Big Island; and a smaller system (approximately 5,000 tons) on southern Kauai. Although the ability to develop projects in these areas would depend on anticipated load growth, local hotel owners expressed an interest and willingness to participate in such a system.

REFERENCES

1. Vega, L.A., 1992. Economics of ocean thermal energy conversion (OTEC). In *Ocean Energy Recovery: The State of the Art*, edited by R.J. Seymour, pp. 152-181. New York, New York: American Society of Civil Engineers.

2. Leitner, G.F., 1991. Total water costs on a standard basis for three large, operating, S.W.R.O. plants. *Desalination*, Vol. 81, pp. 39-48.

3. Makai Ocean Engineering, 1994. *Preliminary State Wide Assessment of Seawatèr Air Conditioning for Hawaii. Phase I: West Beach, Oahu*. Honolulu, Hawaii: Energy Division, Department of Business, Economic Development and Tourism.