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Select Hawaii Renewable Energy Project Cost and Performance Estimates, 2004

Renewable Energy Resource Assessment and Development Program

July 2004

Prepared for:

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Enclosure 2

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SECTION 1. INTRODUCTION

This report, *Select Hawaii Renewable Energy Cost and Performance Estimates, 2004,* is the second update to the initial estimates produced in the *Renewable Energy Resource Assessment and Development Program*, in 1995. All work was done by Global Energy Concepts (formerly RLA Associates). The Program, which was Project 3 of the *Hawaii Energy Strategy* (1995), produced a comprehensive assessment of Hawaii's renewable energy resources (wind, solar, biomass, hydroelectric, ocean thermal energy conversion [OTEC], geothermal, and wave energy) and a long-range development strategy. The project consisted of three parts, as follows:

> **The Renewable Energy Resource Assessment Plan** summarized the activities involved in creating the plan, including determining constraints and requirements, identifying potential project sites, analyzing existing utility infrastructure, identifying existing monitoring sites, and screening potential sites. New solar and wind monitoring sites were recommended and instrumented to collect additional data.
>
> **Development of Renewable Energy Resource Supply Curves** involved compiling cost and performance data on current and future renewable energy conversion systems, analyzing existing data on available resources, and presented the renewable energy resource supply curves that were developed.
>
> **The Renewable Energy Integration Plan** completed collection of new wind and solar data, updated the resource supply curves to reflect the additional data, and developed a plan to integrate the most cost-effective renewable energy projects into Hawaii's energy supply mix. Viable renewable energy projects were prioritized by technology and project site for each of Hawaii's four major islands.

In addition, in November 2000, Global Energy Concepts (GEC) produced *An Update of Selected Cost and Performance Estimates* as an appendix and data input to *An Analysis of Renewable Portfolio Standard Options for Hawaii*, produced by GDS Associates.

Purpose. The principal purpose of this *Select Hawaii Renewable Energy Cost and Performance Estimates, 2004* is to demonstrate the availability of renewable energy resources to meet Hawaii's Renewable Portfolio Standard mandate and the Governor's goal of 20% renewable energy by 2020. A second purpose is to identify renewable energy deployment opportunities for utilities and renewable energy developers since these entities frequently ask the Strategic Industries Division of the State of Hawaii for such information. In some instances, the information may be used to determine whether or not to commit additional resources to a project. A third purpose is to provide renewable energy cost and performance information for consideration in utility Integrated Resource Planning (IRP). Hawaiian Electric Company's and Hawaii Electric Light Company's IRPs are currently in progress. Historically, the State of Hawaii Department

of Business, Economic Development and Tourism's (DBEDT) data from these reports on renewable energy have been cited by utility consultants in the IRP process. Fourth, the data will be used in development of Hawaii Energy Strategy 2005.

Contributing to DBEDT's Mission. This report will contribute to the mission of the DBEDT Director. As the State Energy Resources Coordinator, the DBEDT Director is responsible for planning and policy activities related to energy use in Hawaii. These plans must be consistent with provisions of Chapter 226-18(a) of the Hawaii Revised Statutes, which states that the State's energy planning efforts be: "directed toward the achievement of the following objectives, giving due consideration to all:

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

In addition, DBEDT notes that the following benefits will accrue when more renewable energy resources are installed:

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

The 2004 Report: As with the 2000 update, this report provides an update of the cost and performance estimates for a subset of those projects presented in the original 1995 report. The selected projects focus on the renewable energy technologies and representative project locations that appear to be most economic and promising for application in Hawaii in the next 10-15 years. Although other projects using the selected technologies and other technologies are certainly possible, these projects offer near-term opportunities and provide a representative sampling of what could potentially be done in the state. All of the projects described in this report have been updated to reflect current cost and performance expectations for their respective technologies. Some of the projects are the same as those described in the 2000 report; some are similar with slight variation in conversion technology or size; and some are additions to the original project list.

SECTION 2. APPROACH TO DEVELOPING COST AND PERFORMANCE ESTIMATES

In order to estimate cost and performance for renewable energy projects in Hawaii, GEC compiled current cost and performance data for each of the renewable energy conversion technologies to be evaluated. For this effort, technologies were limited to wind, photovoltaics, hydroelectric, geothermal, and municipal solid waste. Each estimate was based on site-specific resource data and other information. Technology data worksheets were then developed to summarize the detailed information for the project in an accurate and consistent manner. Technology Data Sheets for each project are included in Appendix A.

General Assumptions and Overall Approach

In developing cost and performance estimates, GEC 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 deploy a project in Hawaii. The results are realistic estimates bounded by optimistic and conservative ranges that express the uncertainty associated with technology development or resource availability. 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 and the difference between the expected and actual 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.

For most technologies, three conceptual project designs were developed. One design was based on project components that are commercially available for installation within the next year (current technology). The second design was based on components that are realistically expected to be commercially deployed within the next decade (2014 technology). The third design was based on long-term expectations of technology advances (2020 technology).

Project performance estimates are based on the conceptual project designs, expected technology performance, potential project sizes, and the best available resource data. The net energy estimates are the amount of energy expected to be delivered to the utility grid.

Costing Approach

Costs shown on the technology data worksheets are estimated in a manner that is consistent with the Electric Power Research Institute (EPRI) Technology Assessment Guide (TAG) method of evaluating utility generating alternatives. Capital Costs include Total Project Costs and Initial Costs. Four components comprise Total Project Costs: process capital, general facilities capital, engineering and overhead, and project contingency. The percentages shown are based on TAG guidelines and industry experience. Each of the components of the Total Project 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 are based on site layouts consistent with the geographic and topographic constraints at each project location. 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., which are required for project operations, but do not directly contribute to the production of the energy end product.
>
> ***Engineering and Overhead*** is assumed to be 7%-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.
>
> ***Initial Costs*** reflect the cost of supplies needed on hand to begin operating the power project. Initial or start-up costs include the equivalent of 25% of the annual operating costs, 2% of Total Project Costs to account for any last minute changes, and the capital required for inventory of spare parts or other miscellaneous expenses.

Annual Expenses include the annual costs associated with project operation, which are divided into two basic categories: variable and fixed. 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 landowner. For consistency, land lease costs were estimated for different categories of landownership (DHHL, State, U.S. Navy, and private) and were applied consistently among projects.

In order to adjust U.S. mainland based costs to Hawaii, cost indexes from the *R. S. Means Building Construction Cost Data, 2004* were applied. This document specifies indexes for materials and installation of various construction-related projects for use in adjusting costs between U.S. cities. Table 1 lists the index between the U.S. mainland and Honolulu, Hawaii. Additional cost information on labor rates, equipment rental, and construction processes was obtained from companies involved with projects on Hawaii's four major islands, and this information was applied as appropriate.

Table 1
Hawaii Construction Cost Index, 2004

Construction Category	Material	Installation	Total
Equipment Rental	0.0	99.3	99.3
Site Construction	138.9	106.5	114.7
Concrete	154.7	134.3	144.2
Masonry	134.4	131.7	132.7
Metals	115.7	108.4	112.9
Wood & Plastics	95.0	149.6	124.4
Thermal & Moisture Protection	113.2	131.8	122.2
Doors & Windows	105.9	137.7	113.9
Finishes	135.5	145.9	141.1
Other Divisions	100.0	122.9	104.9
Mechanical	100.1	120.6	109.5
Electrical	113.2	122.9	118.9
Weighted Average	117.6	126.1	121.7

R. S. Means Building Construction Cost Data, 2004

Transmission upgrades were estimated in 1995 based on discussions with utility personnel about available capacity on existing lines and planned upgrades, unit costs for materials and equipment, and estimated distances to interconnection points. Because additional information about the loading and upgrade costs was not available from the utilities in Hawaii for this report, the 1995 estimates were used and adjusted for inflation to 2004.

Technology-Specific Assumptions

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

Wind

Technology Status: Wind energy technology has been commercially deployed on a large scale for over two decades. Technology advances continue to improve wind energy performance and reliability, as well as reduce costs. Since the 2000 update, wind energy dramatically increased deployment; currently more than 40,000 MW are installed worldwide. With increased deployment, reliability and performance have also improved.

For this study, current equipment cost and performance estimates reflect wind technology that is currently being bid for projects in the U.S. in 2004. Given technology advances currently under development and expected to be achievable in the next 10-15 years, forecasted percentage changes in costs and performance were applied to the current estimates to achieve the future estimates.

For some of the potential wind projects updated in this report, a number of possible project sizes were evaluated based on several factors. First, the size and characteristics of the available land parcels were considered. Second, the capacity of the existing transmission lines was used to define potential project sizes. For most locations, transmission upgrades are required for projects above a certain size. This report assumes that major transmission upgrades have not occurred in the last 5 years; therefore, either the estimates developed in 1995 or the information in HECO's most recent Integrated Resource Plans, if appropriate and available, were used to determine the transmission upgrade requirements needed for each project. Third, the size of the utility grid was also considered. For islands other than Oahu, it was assumed that the size of the existing utility grid and the projected demand growth would limit project size to approximately 30 MW. Other constraints at specific sites can further reduce project size.

Since wind energy is currently one of the more economic of the renewable energy options and there has been significant development interest in wind energy in Hawaii, all of the wind projects evaluated in the 2000 update are included in this 2004 report. On the Big Island, three project locations were included in the update: Kahua Ranch, Lalamilo Wells, and North Kohala. Multiple project sizes were evaluated at each site to illustrate what could be done at these locations. A wind project is currently under consideration at the North Kohala site. Because development of the North Kohala site utilizes all the existing transmission capacity for the Kahua Ranch site, Kahua Ranch was evaluated as a potential project only in future scenarios. Good wind resources also exist at the southern tip of the Big Island. Because a wind project is already operating at this location, it was not included in the project list; however, an upgrade to the Southpoint project or expansion of this project may be possible in the future.

On Kauai, representative projects at the North Hanapepe and Port Allen sites were considered in this update. Since the 2000 update, a potential wind development project proposed for the North Hanapepe area has encountered opposition from a landowner and some local citizens. As a result, the North Hanapepe site is not included as a current option but, because public acceptance can change and the North Hanapepe resource represents a larger area, the project has been included in the future scenarios. The southern coastal area to the east of these locations may also have similar winds according to the latest wind map for Kauai.

On Maui, representative projects at Kaheawa Pastures, NW Haleakala, and Puunene were considered in this update. Kaheawa Pastures was referred to as McGregor Point in previous reports. A wind project is currently under development at this site and the name was changed to be consistent with the name used by the project developer. Because this project is currently under development, it is only included as a current project. For the future scenarios, it is assumed that the project is already operating and, as a result, only a 10 MW expansion of this project is included.

On Oahu, the costs and performance estimates at Kaena Point and Kahuku are considered to be representative of projects that could be done on Oahu. Recently updated wind maps indicate that good wind resources are also available in the Makakilo City area and other locations to the west. However, because it is beyond the scope of this document to investigate these areas for development potential and no specific wind resource data is available for analysis, these newly-identified locations are not included in the update. It should be noted that if these areas do prove to have wind energy development potential, the cost and performance estimates for Kaena Point and Kahuku provide reasonable estimations for various size projects that may be developed at these sites.

Performance Assumptions: Since the 2000 update, more detailed wind maps using advanced mapping techniques have been developed for the major islands of Hawaii. Review of the latest wind resource maps show that all the wind sites are located within areas of at least 6.5 m/s average wind speeds at a height of 50 m. Estimates of the wind resource at specific representative project sites were based on the same historical site wind speed data used in the 1995 study. A power curve from a representative wind turbine was used to estimate per-turbine production at each site. In addition, the following assumptions were made:

- Wind resource data sets were adjusted to reflect the hub height wind speeds of the new turbine technology based on the measured shear at the site. If there were no on-site wind shear data available, estimates for the shear characteristics were based on shear factors measured in areas with similar terrain or exposure to the trade winds.

- Estimated energy losses were determined on a site-specific basis and range from 16%-26%. Energy losses account for array effects, downtime, line losses, blade soiling, control inefficiencies, and turbulence. The array losses are slightly less

than assumed in the 2000 update because a larger turbine size was assumed for installation in 2004.

- A 900 kW wind turbine typical of commercially available technology was used for cost and performance estimates for the current time frame. The representative wind turbine has a 52-m rotor mounted on a 60-m tower. Even though turbines of 1-2 MW are currently available, a larger number of smaller turbines may offer a better fit with the islands' power grids by offering less fluctuation across the project site. In addition, the crane capacity currently available on the islands should accommodate installation of this size turbine.

- For future technology, a 1.5 MW turbine with a 70-m rotor diameter mounted on a 65-m self-erecting tower was assumed. The weight and mounting height of multi-megawatt machines requires heavy duty conventional cranes or truck cranes. Conversations with Hawaiian based crane companies revealed that the largest crane available to date is a 350-ton all-terrain truck crane. To install future projects, either a crane/truck crane would have to be shipped overseas or self-erecting towers employed. Self-erecting towers may be available by the 2014 time frame. Although more expensive than standard towers and foundations, these towers may be cost effective in remote locations such as Hawaii. This offers just one of several viable options. Depending on specific project economics and the number of sites to be developed, it may be feasible to buy a heavy-duty crane, ship it to Hawaii, and leave it there for future projects.

Cost Basis: Itemized costs were developed for each nominal current technology case using the best currently available information. Future costs were estimated based on cost reduction projections made 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 were adjusted to account for costs in Hawaii and are expressed in terms of 2004 dollars.

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

- Parametric costs were developed for balance-of-station costs and construction costs based on types of terrain (dirt, rocky, lava) and wind regimes to account for different 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 adjusted based on project size to reflect larger production run discounts. A discount was applied to the equipment costs for projects 50 MW or larger and a surcharge was added to projects 5 MW or smaller.

- A 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.

Photovoltaics

Technology Status: Although a large market exists for photovoltaics (PV) for remote power applications and consumer products, experience with large-scale photovoltaic installations for bulk electricity generation is limited. However, multiple demonstration projects are installed throughout the U.S. and the cost and performance estimates for current projects in this study are based on experience with recent demonstration projects. Future cost and performance estimates are scaled from current technology values based on industry estimates of improved efficiency and the cost advantages associated with mass production.

The two projects from the 2000 update are included in this report. These two projects represent what could be done in a number of different locations in Hawaii. Remote, or off-grid PV applications, are also very promising since they do not require significant amounts of land, and are discussed in Appendix B.

Performance Assumptions: The solar resource data used for the PV performance estimates in 1995 were also used for this update. The variations between optimistic, nominal, and conservative performance estimates account for the uncertainty in the resource data. In addition, the following assumptions were made:

- Fixed systems were assumed to face due south at a 15-degree tilt angle.

- Current technology assumes a 10.5% project ac efficiency, 13.3% in the 2014 timeframe, and 15% in the 2020 timeframe.

- Energy losses and the array field layouts are assumed to be the same as in the 2000 update.

Cost Basis: The following cost assumptions were made:

- Equipment costs are based on recent information from equipment manufacturers and experience with demonstration projects. Module costs have decreased approximately 27% since 2000, to $2.6/Wac, and modest decreases are assumed for future scenarios. Both Power Condition Unit and array structure costs have decreased from earlier estimates.

- Parametric costs were developed for foundations and construction based on different soil types.

- For future technology, infrastructure costs were reduced due to the increased efficiency of the modules (fewer modules are necessary for the same size project).

Hydroelectric

Technology Status: Hydroelectric is a mature technology. Few appreciable differences exist between the types of projects that were considered in 1995 and 2000 and those that could be installed in 2004. New projects are expected to have slightly lower operation and maintenance costs than existing projects, resulting from semi-automatic operating controls and improvements in designs.

Permitting and satisfactory environmental mitigation plans can still make developing a hydroelectric project a challenge. Some ways to reduce these challenges include choosing a run-of-river configuration over a storage configuration, and keeping the project size small. The representative projects in this study are both under 15 MW and are run-of-river. Although hydroelectric development has not occurred on the Big Island in over 10 years, the potential for development still exists along the Umauma Stream. The Wailua River on Kauai has experienced more recent development investigations, but a project has not been built. Both projects are still included in the 2004 report to suggest what might be possible in the future. However, because there are no development activities currently underway, hydroelectric projects are only considered in the future scenarios.

Performance Assumptions: No changes were made in the performance predictions for the hydroelectric project for 2004. 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 stream flows and river ecology. Energy losses account for power transformation and transmission to the utility grid.

Cost Basis: The 1995 cost estimates were based on recent experience with hydroelectric project development both within Hawaii and at other mainland locations. For this update, the costs were simply adjusted for inflation.

Geothermal

Technology Status: Geothermal energy conversion has been used for hundreds of years. Use for electrical energy began in the 1900s, with large-scale commercial deployment from high temperature (>150 deg. C), water-dominated resource areas starting in the mid-1900s. While research and development efforts continue, the technology is not expected to drastically change in the next 10-20 years.

Cost estimates in this study reflect conventional binary technology, which is expected to be comparable to the cost of a hybrid system (binary and flash) like the one currently used at a geothermal facility operating on the Big Island in the Kilauea east rift zone. Performance estimates are based on the estimated performance of the existing project. Previous evaluations of this resource indicate that an additional 30 MW or more could be generated from this existing facility. Significant potential for additional geothermal facilities on the other islands also exists. The potential geothermal project included in the future scenarios of this report is a new 30 MW project of a similar configuration to the existing project, and illustrates what could be done at the existing site or other sites along the geothermal resource zone.

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

- A normal amount of site and well variation is assumed relative to the experience of the existing power project location.
- The exact project 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: Costs were based on knowledge of the costs associated with the existing facility and with similarly sized geothermal projects adjusted to account for Hawaii-specific cost factors.

Biomass and Waste-to-Energy

Technology Status: Several methods for converting biomass to energy exist including direct fired boilers, co-firing, and gasification. A significant amount of biomass conversion technology research focuses on gasification. Companies developing this technology hope that it will be cost competitive at the distributed generation level in the next 10-15 years. The source of biomass could be agricultural or municipal solid waste (MSW).

In recent years the agricultural sector in Hawaii has changed. All of the sugar plantations have closed except for HC&S on Maui and Gay and Robinson on Kauai, and the amount of energy generated by biomass associated with the sugar industry has been drastically reduced. Due to the uncertainties associated with agricultural production and its use for

biomass energy in Hawaii, new agricultural biomass technology data sheets were not developed for the 2004 update.

However, MSW is a viable option on several of the islands. Currently, an MSW waste-to-energy facility operates on Oahu. The City and County of Honolulu are considering adding another boiler to reduce the amount of refuse going to the landfill during boiler maintenance. At peak energy demand times, the third boiler could be operated to produce an additional 8 MW of energy, and is expected to handle an additional 125,000 tons/yr. To date, the facility has processed over 8 million tons of waste and saved approximately 500 acres of Oahu from landfill use. In 2002, the facility supplied 4% of HECO's electric sales. Furthermore, the counties of Hawaii, Maui, and Kauai are each in various stages of evaluating the potential for waste-to-energy facilities.

A recent study conducted on behalf of the Hawaii Energy Policy Forum estimated refuse tonnage and energy production for gasification and direct-fired technologies on each of the islands. Based on the various MSW energy potentials across the islands, a viable future option is a 10 MW simple cycle MSW gasification unit. This study assumes a project location on the east side of the Big Island in the future scenarios, but it also represents what could be done on Maui or Kauai in the future. Though not studied in this report, another future option is the production of landfill methane gas, which could then be burned in a gas turbine.

Performance Assumptions: Biomass gasification technology is just now gaining ground in Europe and Japan. The industry expects the technology to overtake direct-fired technology in waste-to-energy applications in the U.S. in the next 5-10 years. A recent study by NREL described the capabilities of small-scale simple cycle gas turbines for use in distributed generation applications. Burning natural gas, current capacity factors would average 75%-80%, with improvements of 10%-25% in the near-term. Burning lower Btu fuels like biogas, along with the ash, would degrade performance quicker. Given the degradation potential and the potential for efficiency and heat rate improvements, a 75% capacity factor is assumed for the future project.

Cost Basis: The costs assumed in this study are based on the NREL small-scale simple cycle costs for a 10 MW machine, as well as the estimated cost from the 1995 report for an organic waste gasification waste-to-energy facility. The costs were scaled using the 0.7 law employed by NREL in its cost estimates when scaling between different sizes of the same technology. This states that costs for one sized machine are roughly equal to the ratio of the capacities raised to 0.7. The annual operating costs also include a tipping fee for refuse disposal (shown as a negative value on the Technology Data Sheets because it is a source of income rather than an expense). The assumed fee is $25/ton based on information on the DBEDT website.

SECTION 3. RENEWABLE ENERGY PROJECTS INCLUDED IN THE 2004 UPDATE

Table 2 lists the current and future projects for which Year 2004 cost and performance updates were completed as part of this effort. Additional information on the process to identify project sites and the characteristics of each project site are included in the 1995 report, *Renewable Energy Resource Assessment and Development Program.*

As previously noted, these projects are representative of renewable energy projects that could be developed in Hawaii but the list is not necessarily comprehensive. A number of additional technically-viable projects may exist on each island.

TABLE 2
Current and Future Representative Projects Included in the 2004 Update

Technology	Island	Location	Capacity (MW)
Biomass	Hawaii [1]	East Island [1]	10
Geothermal	Hawaii	Kilauea	10
Hydroelectric	Hawaii	Umauma Stream [2]	13.8
	Kauai	Wailua River [2]	6.6
Photovoltaic	Hawaii	N. Kohala	5
	Oahu	Pearl Harbor	5
Wind	Hawaii	Lalamilo Wells	3, 30, 50
		N. Kohala	5, 10
		Kahua Ranch [2]	10
	Kauai	N. Hanapepe [2]	10
		Port Allen	5
	Maui	Kaheawa Pastures	20, 10 expansion
		NW Haleakala	10, 30, 50
		Puunene	10, 30
	Oahu	Kaena Point	3, 15
		Kahuku	30, 50, 80

[1] This project is included in the future scenarios, and also illustrates what could also be done on Maui and Kauai.
[2] Only included in future cost scenarios.

Although the database does not include project sites for either Lanai or Molokai, renewable energy has potential on these islands for use in small-scale applications. Descriptions of small-scale renewable energy technologies and applications that may be appropriate for these islands, as well as on the larger islands in certain locations are included in Appendix B. This information is included to illustrate that grid-connected, bulk-power renewable energy technologies are not the only viable approach to incorporating renewable energy into Hawaii's overall energy strategies.

Tables 3, 4, and 5 list the calculated cost of energy (COE) for the included current and future projects, respectively. The COE calculation is based on the EPRI TAG methodology, and provides a consistent means by which to compare the various renewable energy projects considered in this study.

Table 3
Representative Projects – Current

Technology	Island	Location	Capacity (MW)	Nominal Energy (MWh)	COE ($/kWh)
Photovoltaics	Hawaii	N. Kohala	5	11,695	0.219
	Oahu	Pearl Harbor	5	10,257	0.257
Wind	Hawaii	Lalamilo Wells	3	9,154	0.047
		Lalamilo Wells	30	92,802	0.047
		Lalamilo Wells	50	154,670	0.045
		N. Kohala	5	17,469	0.044
		N. Kohala	10	38,840	0.047
	Kauai	Port Allen	5	9,774	0.069
	Maui	Kaheawa Pastures	20	70,338	0.043
		NW Haleakala	10	27,493	0.052
		NW Haleakala	30	75,214	0.060
		NW Haleakala	50	125,357	0.057
		Puunene	10	20,689	0.068
		Puunene	30	56,601	0.078
	Oahu	Kaena Point	3	6,461	0.066
		Kaena Point	15	33,201	0.066
		Kahuku	30	68,181	0.063
		Kahuku	50	113,635	0.063
		Kahuku	80	181,816	0.066

Table 4
Representative Projects – Future 2014

Technology	Island	Location	Capacity (MW)	Nominal Energy (MWh)	COE ($/kWh)
Biomass	Hawaii	East Side of Island	10	65,700	0.051
Geothermal	Hawaii	Kilauea	10	252,200	0.058
Hydroelectric	Hawaii	Umauma Stream	13.8	40,199	0.083
	Kauai	Wailua River	6.6	16,435	0.101
Photovoltaics	Hawaii	N. Kohala	5	12,136	0.168
	Oahu	Pearl Harbor	5	10,643	0.199
Wind	Hawaii	Lalamilo Wells	3	12,115	0.045
		Lalamilo Wells	30	111,857	0.046
		Lalamilo Wells	50	184,565	0.044
		N. Kohala	5	20,977	0.042
		N. Kohala	10	41,534	0.046
		Kahua Ranch	10	31,384	0.052
	Kauai	N. Hanapepe	10	22,627	0.068
		Port Allen	5	11,393	0.069
	Maui	Kaheawa Pastures	10 expansion	37,471	0.039
		NW Haleakala	10	30,748	0.050
		NW Haleakala	30	95,097	0.056
		NW Haleakala	50	156,910	0.053
		Puunene	10	22,499	0.066
		Puunene	30	69,583	0.074
	Oahu	Kaena Point	3	8,628	0.063
		Kaena Point	15	41,602	0.063
		Kahuku	30	84,302	0.060
		Kahuku	50	139,098	0.059
		Kahuku	80	223,400	0.062

Table 5
Representative Projects – Future 2020

Technology	Island	Location	Capacity (MW)	Nominal Energy (MWh)	COE ($/kWh)
Biomass	Hawaii	East Side of Island	10	65,700	0.044
Geothermal	Hawaii	Kilauea	10	252,200	0.058
Hydroelectric	Hawaii	Umauma Stream	13.8	40,199	0.082
	Kauai	Wailua River	6.6	16,435	0.100
Photovoltaics	Hawaii	N. Kohala	5	12,280	0.128
	Oahu	Pearl Harbor	5	10,769	0.152
Wind	Hawaii	Lalamilo Wells	3	13,932	0.039
		Lalamilo Wells	30	128,636	0.040
		Lalamilo Wells	50	212,249	0.038
		N. Kohala	5	24,123	0.036
		N. Kohala	10	47,764	0.040
		Kahua Ranch	10	36,091	0.045
	Kauai	N. Hanapepe	10	26,021	0.058
		Port Allen	5	13,102	0.060
	Maui	NW Haleakala	10	35,360	0.043
		NW Haleakala	30	109,362	0.048
		NW Haleakala	50	180,447	0.046
		Puunene	10	25,873	0.057
		Puunene	30	80,021	0.064
	Oahu	Kaena Point	3	9,922	0.054
		Kaena Point	15	47,842	0.054
		Kahuku	30	96,947	0.052
		Kahuku	50	159,963	0.051
		Kahuku	80	256,910	0.054

APPENDIX A. TECHNOLOGY DATA SHEETS

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	3		Stage (current/future)		current
Resource (mph, avg)	23		Extent (# of units)		3
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	12,610	11,464	10,318
Expected Losses (%)	15.1%	20.1%	25.1%
Net Energy (MWh/yr)	10,700	9,154	7,723
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$1,903,136	$1,941,975	$1,980,815
Foundations	$286,165	$292,005	$297,845
Assembly & Checkout	$63,504	$64,800	$66,096
Electrical Infrastructure	$78,652	$80,258	$81,863
Sub-Station	$132,300	$135,000	$137,700
Overseas Shipping	$73,500	$75,000	$76,500
Legal Fees & Permitting	$282,918	$353,647	$442,059
General Capital Facilities			
Roads & Grading	$29,226	$29,822	$30,418
Control System	$21,168	$21,600	$22,032
Control Buildings	$5,292	$5,400	$5,508
Central Building	$11,610	$12,900	$16,125
Engineering & Overhead	$197,412	$205,988	$215,801
Project Contingency	$308,488	$321,839	$337,276
Initial Costs	$166,638	$170,827	$175,272
SUB-TOTAL	$3,560,008	$3,711,061	$3,885,310
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$28,890	$27,462	$25,485
Fixed O&M	$22,275	$22,500	$22,725
Land Lease	$3,762	$3,960	$4,158
FIRST YEAR O&M	$54,927	$53,922	$52,368

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		current
Resource (mph, avg)	23		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	138,714	126,104	113,494
Expected Losses (%)	21.4%	26.4%	31.4%
Net Energy (MWh/yr)	109,018	92,802	77,847
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$19,937,610	$20,344,500	$20,751,390
Foundations	$3,147,814	$3,212,055	$3,276,296
Assembly & Checkout	$698,544	$712,800	$727,056
Electrical Infrastructure	$865,176	$882,833	$900,489
Sub-Station	$1,323,000	$1,350,000	$1,377,000
Overseas Shipping	$808,500	$825,000	$841,500
Legal Fees & Permitting	$333,583	$416,979	$521,224
General Capital Facilities			
Roads & Grading	$265,278	$270,692	$276,106
Control System	$232,848	$237,600	$242,352
Control Buildings	$58,212	$59,400	$60,588
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$1,897,996	$1,942,092	$1,987,647
Project Contingency	$2,965,559	$3,035,065	$3,108,252
Initial Costs	$1,697,221	$1,727,763	$1,757,619
SUB-TOTAL	$34,318,371	$35,113,478	$35,948,394
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$294,348	$278,406	$256,895
Fixed O&M	$245,025	$247,500	$249,975
Land Lease	$41,382	$43,560	$45,738
FIRST YEAR O&M	$580,755	$569,466	$552,608

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	50		Stage (current/future)		current
Resource (mph, avg)	23		Extent (# of units)		55
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	231,191	210,173	189,156
Expected Losses (%)	21.4%	26.4%	31.4%
Net Energy (MWh/yr)	181,696	154,670	129,745
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$32,564,763	$33,229,350	$33,893,937
Foundations	$5,246,357	$5,353,425	$5,460,494
Assembly & Checkout	$1,164,240	$1,188,000	$1,211,760
Electrical Infrastructure	$1,441,960	$1,471,388	$1,500,815
Sub-Station	$2,205,000	$2,250,000	$2,295,000
Overseas Shipping	$1,347,500	$1,375,000	$1,402,500
Legal Fees & Permitting	$369,412	$461,765	$577,207
General Capital Facilities			
Roads & Grading	$438,383	$447,330	$456,277
Control System	$388,080	$396,000	$403,920
Control Buildings	$97,020	$99,000	$100,980
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$3,103,746	$3,173,025	$3,243,920
Project Contingency	$4,845,349	$4,954,098	$5,066,768
Initial Costs	$2,777,214	$2,826,104	$2,873,426
SUB-TOTAL	$56,076,055	$57,321,185	$58,607,878
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$490,580	$464,010	$428,159
Fixed O&M	$408,375	$412,500	$416,625
Land Lease	$68,970	$72,600	$76,230
FIRST YEAR O&M	$967,925	$949,110	$921,014

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	North Kohala	Project Code:	(leave blank)
Capacity (MW)	5		Stage (current/future)		current
Resource (mph, avg)	23		Extent (# of units)		5
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	24,065	21,877	19,689
Expected Losses (%)	15.1%	20.1%	25.1%
Net Energy (MWh/yr)	20,419	17,469	14,738
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$3,171,893	$3,236,625	$3,301,358
Foundations	$524,636	$535,343	$546,049
Assembly & Checkout	$105,840	$108,000	$110,160
Electrical Infrastructure	$131,087	$133,763	$136,438
Sub-Station	$220,500	$225,000	$229,500
Overseas Shipping	$122,500	$125,000	$127,500
Legal Fees & Permitting	$286,611	$358,264	$447,830
General Capital Facilities			
Roads & Grading	$50,583	$51,615	$52,647
Control System	$35,280	$36,000	$36,720
Control Buildings	$8,820	$9,000	$9,180
Central Building	$40,590	$45,100	$56,375
Engineering & Overhead	$319,415	$330,540	$342,918
Project Contingency	$501,775	$519,425	$539,667
Initial Costs	$280,328	$286,532	$292,968
SUB-TOTAL	$5,799,857	$6,000,205	$6,229,310
TRANSMISSION			
Cost of Upgrade	$389,425	$397,373	$405,320
ANNUAL EXPENSES			
Variable O&M	$55,131	$52,407	$48,634
Fixed O&M	$37,125	$37,500	$37,875
Land Lease	$18,810	$19,800	$20,790
FIRST YEAR O&M	$111,066	$109,707	$107,299

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	North Kohala	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		current
Resource (mph, avg)	23		Extent (# of units)		11
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	52,942	48,129	43,316
Expected Losses (%)	14.3%	19.3%	24.3%
Net Energy (MWh/yr)	45,371	38,840	32,790
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,645,870	$6,781,500	$6,917,130
Foundations	$1,154,198	$1,177,754	$1,201,309
Assembly & Checkout	$232,848	$237,600	$242,352
Electrical Infrastructure	$288,392	$294,278	$300,163
Sub-Station	$441,000	$450,000	$459,000
Overseas Shipping	$269,500	$275,000	$280,500
Legal Fees & Permitting	$296,637	$370,796	$463,495
General Capital Facilities			
Roads & Grading	$104,538	$106,671	$108,804
Control System	$77,616	$79,200	$80,784
Control Buildings	$19,404	$19,800	$20,196
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$652,991	$671,085	$690,476
Project Contingency	$1,027,002	$1,056,038	$1,088,508
Initial Costs	$586,024	$597,506	$609,067
SUB-TOTAL	$11,883,051	$12,213,928	$12,582,660
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$122,503	$116,521	$108,209
Fixed O&M	$81,675	$82,500	$83,325
Land Lease	$41,382	$43,560	$45,738
FIRST YEAR O&M	$245,560	$242,581	$237,272

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Kauai	Location:	Port Allen	Project Code:	(leave blank)
Capacity (MW)	5		Stage (current/future)		current
Resource (mph, avg)	16		Extent (# of units)		5
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	12,724	11,567	10,410
Expected Losses (%)	10.5%	15.5%	20.5%
Net Energy (MWh/yr)	11,388	9,774	8,277
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$3,171,893	$3,236,625	$3,301,358
Foundations	$476,942	$486,675	$496,409
Assembly & Checkout	$105,840	$108,000	$110,160
Electrical Infrastructure	$131,087	$133,763	$136,438
Sub-Station	$220,500	$225,000	$229,500
Overseas Shipping	$122,500	$125,000	$127,500
Legal Fees & Permitting	$286,502	$358,128	$447,660
General Capital Facilities			
Roads & Grading	$44,962	$45,880	$46,798
Control System	$35,280	$36,000	$36,720
Control Buildings	$8,820	$9,000	$9,180
Central Building	$40,590	$45,100	$56,375
Engineering & Overhead	$316,068	$327,123	$339,432
Project Contingency	$496,098	$513,629	$533,753
Initial Costs	$270,029	$276,371	$283,059
SUB-TOTAL	$5,727,111	$5,926,293	$6,154,339
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$30,748	$29,323	$27,313
Fixed O&M	$37,125	$37,500	$37,875
Land Lease	$6,270	$6,600	$6,930
FIRST YEAR O&M	$74,143	$73,423	$72,118

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Kaheawa Pastures	Project Code:	(leave blank)
Capacity (MW)	20		Stage (current/future)		current
Resource (mph, avg)	21		Extent (# of units)		22
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	93,057	84,597	76,137
Expected Losses (%)	11.9%	16.9%	21.9%
Net Energy (MWh/yr)	82,025	70,338	59,498
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$13,291,740	$13,563,000	$13,834,260
Foundations	$2,308,397	$2,355,507	$2,402,617
Assembly & Checkout	$465,696	$475,200	$484,704
Electrical Infrastructure	$769,045	$784,740	$800,435
Sub-Station	$893,025	$911,250	$929,475
Overseas Shipping	$539,000	$550,000	$561,000
Legal Fees & Permitting	$316,019	$395,023	$493,779
General Capital Facilities			
Roads & Grading	$269,400	$274,898	$280,396
Control System	$155,232	$158,400	$161,568
Control Buildings	$38,808	$39,600	$40,392
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$1,300,805	$1,332,430	$1,365,439
Project Contingency	$2,043,420	$2,093,675	$2,147,494
Initial Costs	$1,164,150	$1,186,020	$1,207,520
SUB-TOTAL	$23,641,766	$24,216,443	$24,829,954
TRANSMISSION			
Cost of Upgrade	$757,216	$772,669	$788,122
ANNUAL EXPENSES			
Variable O&M	$221,468	$211,015	$196,342
Fixed O&M	$163,350	$165,000	$166,650
Land Lease	$82,764	$87,120	$91,476
FIRST YEAR O&M	$467,582	$463,135	$454,468

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		current
Resource (mph, avg)	19		Extent (# of units)		11
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	36,184	32,895	29,605
Expected Losses (%)	11.4%	16.4%	21.4%
Net Energy (MWh/yr)	32,052	27,493	23,263
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,645,870	$6,781,500	$6,917,130
Foundations	$1,049,271	$1,070,685	$1,092,099
Assembly & Checkout	$232,848	$237,600	$242,352
Electrical Infrastructure	$288,392	$294,278	$300,163
Sub-Station	$441,000	$450,000	$459,000
Overseas Shipping	$269,500	$275,000	$280,500
Legal Fees & Permitting	$296,398	$370,497	$463,121
General Capital Facilities			
Roads & Grading	$92,173	$94,054	$95,935
Control System	$77,616	$79,200	$80,784
Control Buildings	$19,404	$19,800	$20,196
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$645,630	$663,569	$682,806
Project Contingency	$1,014,513	$1,043,288	$1,075,496
Initial Costs	$574,683	$586,596	$598,758
SUB-TOTAL	$11,734,327	$12,062,767	$12,429,214
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$86,539	$82,479	$76,769
Fixed O&M	$81,675	$82,500	$83,325
Land Lease	$41,382	$43,560	$45,738
FIRST YEAR O&M	$209,596	$208,539	$205,832

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		current
Resource (mph, avg)	19		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	108,553	98,685	88,816
Expected Losses (%)	18.8%	23.8%	28.8%
Net Energy (MWh/yr)	88,163	75,214	63,252
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$19,937,610	$20,344,500	$20,751,390
Foundations	$3,147,814	$3,212,055	$3,276,296
Assembly & Checkout	$698,544	$712,800	$727,056
Electrical Infrastructure	$865,176	$882,833	$900,489
Sub-Station	$1,323,000	$1,350,000	$1,377,000
Overseas Shipping	$808,500	$825,000	$841,500
Legal Fees & Permitting	$333,583	$416,979	$521,224
General Capital Facilities			
Roads & Grading	$265,278	$270,692	$276,106
Control System	$232,848	$237,600	$242,352
Control Buildings	$58,212	$59,400	$60,588
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$1,897,996	$1,942,092	$1,987,647
Project Contingency	$2,965,559	$3,035,065	$3,108,252
Initial Costs	$1,703,835	$1,736,352	$1,768,447
SUB-TOTAL	$34,324,985	$35,122,067	$35,959,222
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$238,040	$225,642	$208,731
Fixed O&M	$245,025	$247,500	$249,975
Land Lease	$124,146	$130,680	$137,214
FIRST YEAR O&M	$607,211	$603,822	$595,920

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	50		Stage (current/future)		current
Resource (mph, avg)	19		Extent (# of units)		55
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	180,922	164,475	148,027
Expected Losses (%)	18.8%	23.8%	28.8%
Net Energy (MWh/yr)	146,938	125,357	105,420
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$32,564,763	$33,229,350	$33,893,937
Foundations	$5,246,357	$5,353,425	$5,460,494
Assembly & Checkout	$1,164,240	$1,188,000	$1,211,760
Electrical Infrastructure	$1,441,960	$1,471,388	$1,500,815
Sub-Station	$2,205,000	$2,250,000	$2,295,000
Overseas Shipping	$1,347,500	$1,375,000	$1,402,500
Legal Fees & Permitting	$369,412	$461,765	$577,207
General Capital Facilities			
Roads & Grading	$438,383	$447,330	$456,277
Control System	$388,080	$396,000	$403,920
Control Buildings	$97,020	$99,000	$100,980
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$3,103,746	$3,173,025	$3,243,920
Project Contingency	$4,845,349	$4,954,098	$5,066,768
Initial Costs	$2,788,238	$2,840,419	$2,891,472
SUB-TOTAL	$56,087,078	$57,335,500	$58,625,925
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$396,734	$376,070	$347,885
Fixed O&M	$408,375	$412,500	$416,625
Land Lease	$206,910	$217,800	$228,690
FIRST YEAR O&M	$1,012,019	$1,006,370	$993,200

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Puunene	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		current
Resource (mph, avg)	16		Extent (# of units)		11
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	27,230	24,754	22,279
Expected Losses (%)	11.4%	16.4%	21.4%
Net Energy (MWh/yr)	24,120	20,689	17,506
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,645,870	$6,781,500	$6,917,130
Foundations	$1,154,198	$1,177,754	$1,201,309
Assembly & Checkout	$232,848	$237,600	$242,352
Electrical Infrastructure	$288,392	$294,278	$300,163
Sub-Station	$441,000	$450,000	$459,000
Overseas Shipping	$269,500	$275,000	$280,500
Legal Fees & Permitting	$296,637	$370,796	$463,495
General Capital Facilities			
Roads & Grading	$104,538	$106,671	$108,804
Control System	$77,616	$79,200	$80,784
Control Buildings	$19,404	$19,800	$20,196
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$652,991	$671,085	$690,476
Project Contingency	$1,027,002	$1,056,038	$1,088,508
Initial Costs	$564,782	$576,633	$588,834
SUB-TOTAL	$11,861,809	$12,193,054	$12,562,428
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$65,123	$62,068	$57,771
Fixed O&M	$81,675	$82,500	$83,325
Land Lease	$13,794	$14,520	$15,246
FIRST YEAR O&M	$160,592	$159,088	$156,342

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Puunene	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		current
Resource (mph, avg)	16		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	81,690	74,263	66,837
Expected Losses (%)	18.8%	23.8%	28.8%
Net Energy (MWh/yr)	66,345	56,601	47,599
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$19,937,610	$20,344,500	$20,751,390
Foundations	$3,462,595	$3,533,261	$3,603,926
Assembly & Checkout	$698,544	$712,800	$727,056
Electrical Infrastructure	$865,176	$882,833	$900,489
Sub-Station	$1,323,000	$1,350,000	$1,377,000
Overseas Shipping	$808,500	$825,000	$841,500
Legal Fees & Permitting	$334,301	$417,877	$522,346
General Capital Facilities			
Roads & Grading	$302,372	$308,543	$314,714
Control System	$232,848	$237,600	$242,352
Control Buildings	$58,212	$59,400	$60,588
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$1,920,081	$1,964,639	$2,010,659
Project Contingency	$3,003,027	$3,073,315	$3,147,289
Initial Costs	$1,675,469	$1,707,811	$1,740,012
SUB-TOTAL	$34,708,766	$35,514,278	$36,360,196
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$179,133	$169,803	$157,076
Fixed O&M	$245,025	$247,500	$249,975
Land Lease	$41,382	$43,560	$45,738
FIRST YEAR O&M	$465,540	$460,863	$452,789

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kaena Point	Project Code:	(leave blank)
Capacity (MW)	3		Stage (current/future)		current
Resource (mph, avg)	17		Extent (# of units)		3
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	8,546	7,769	6,992
Expected Losses (%)	11.8%	16.8%	21.8%
Net Energy (MWh/yr)	7,534	6,461	5,465
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$1,903,136	$1,941,975	$1,980,815
Foundations	$286,165	$292,005	$297,845
Assembly & Checkout	$63,504	$64,800	$66,096
Electrical Infrastructure	$104,870	$107,010	$109,150
Sub-Station	$132,300	$135,000	$137,700
Overseas Shipping	$73,500	$75,000	$76,500
Legal Fees & Permitting	$282,987	$353,734	$442,167
General Capital Facilities			
Roads & Grading	$37,094	$37,851	$38,608
Control System	$21,168	$21,600	$22,032
Control Buildings	$5,292	$5,400	$5,508
Central Building	$11,610	$12,900	$16,125
Engineering & Overhead	$199,252	$207,867	$217,719
Project Contingency	$312,088	$325,514	$341,027
Initial Costs	$165,184	$169,505	$174,121
SUB-TOTAL	$3,598,150	$3,750,161	$3,925,413
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$20,343	$19,383	$18,036
Fixed O&M	$22,275	$22,500	$22,725
Land Lease	$3,762	$3,960	$4,158
FIRST YEAR O&M	$46,380	$45,843	$44,919

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kaena Point	Project Code:	(leave blank)
Capacity (MW)	15		Stage (current/future)		current
Resource (mph, avg)	17		Extent (# of units)		16
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	45,577	41,434	37,290
Expected Losses (%)	14.9%	19.9%	24.9%
Net Energy (MWh/yr)	38,800	33,201	28,017
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$9,666,720	$9,864,000	$10,061,280
Foundations	$1,526,213	$1,557,360	$1,588,507
Assembly & Checkout	$338,688	$345,600	$352,512
Electrical Infrastructure	$559,306	$570,720	$582,134
Sub-Station	$661,500	$675,000	$688,500
Overseas Shipping	$392,000	$400,000	$408,000
Legal Fees & Permitting	$305,261	$381,576	$476,970
General Capital Facilities			
Roads & Grading	$173,480	$177,020	$180,561
Control System	$112,896	$115,200	$117,504
Control Buildings	$28,224	$28,800	$29,376
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$941,478	$965,598	$991,053
Project Contingency	$1,479,280	$1,517,757	$1,559,727
Initial Costs	$821,269	$837,620	$854,146
SUB-TOTAL	$17,093,343	$17,532,952	$18,011,146
TRANSMISSION			
Cost of Upgrade	$1,622,605	$1,655,719	$1,688,834
ANNUAL EXPENSES			
Variable O&M	$104,761	$99,604	$92,455
Fixed O&M	$118,800	$120,000	$121,200
Land Lease	$20,064	$21,120	$22,176
FIRST YEAR O&M	$243,625	$240,724	$235,831

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		current
Resource (mph, avg)	18		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	97,850	88,955	80,059
Expected Losses (%)	18.4%	23.4%	28.4%
Net Energy (MWh/yr)	79,892	68,181	57,360
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$19,937,610	$20,344,500	$20,751,390
Foundations	$3,462,595	$3,533,261	$3,603,926
Assembly & Checkout	$698,544	$712,800	$727,056
Electrical Infrastructure	$980,533	$1,000,544	$1,020,554
Sub-Station	$1,323,000	$1,350,000	$1,377,000
Overseas Shipping	$808,500	$825,000	$841,500
Legal Fees & Permitting	$334,617	$418,272	$522,840
General Capital Facilities			
Roads & Grading	$341,939	$348,917	$355,896
Control System	$232,848	$237,600	$242,352
Control Buildings	$58,212	$59,400	$60,588
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$1,928,178	$1,972,906	$2,019,099
Project Contingency	$3,019,361	$3,089,990	$3,164,308
Initial Costs	$1,708,409	$1,741,446	$1,774,168
SUB-TOTAL	$34,921,376	$35,731,335	$36,581,551
TRANSMISSION			
Cost of Upgrade	$973,563	$993,432	$1,013,300
ANNUAL EXPENSES			
Variable O&M	$215,708	$204,544	$189,288
Fixed O&M	$245,025	$247,500	$249,975
Land Lease	$124,146	$130,680	$137,214
FIRST YEAR O&M	$584,879	$582,724	$576,477

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	50		Stage (current/future)		current
Resource (mph, avg)	18		Extent (# of units)		55
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	163,084	148,258	133,432
Expected Losses (%)	18.4%	23.4%	28.4%
Net Energy (MWh/yr)	133,153	113,635	95,600
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$32,564,763	$33,229,350	$33,893,937
Foundations	$5,770,992	$5,888,768	$6,006,543
Assembly & Checkout	$1,164,240	$1,188,000	$1,211,760
Electrical Infrastructure	$1,634,221	$1,667,573	$1,700,924
Sub-Station	$2,205,000	$2,250,000	$2,295,000
Overseas Shipping	$1,347,500	$1,375,000	$1,402,500
Legal Fees & Permitting	$371,136	$463,920	$579,900
General Capital Facilities			
Roads & Grading	$566,152	$577,706	$589,260
Control System	$388,080	$396,000	$403,920
Control Buildings	$97,020	$99,000	$100,980
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$3,154,050	$3,224,383	$3,296,339
Project Contingency	$4,935,018	$5,045,640	$5,160,194
Initial Costs	$2,795,860	$2,848,909	$2,901,008
SUB-TOTAL	$57,081,062	$58,350,948	$59,663,140
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$359,513	$340,906	$315,480
Fixed O&M	$408,375	$412,500	$416,625
Land Lease	$206,910	$217,800	$228,690
FIRST YEAR O&M	$974,798	$971,206	$960,795

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	80		Stage (current/future)		current
Resource (mph, avg)	18		Extent (# of units)		88
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	260,934	237,213	213,492
Expected Losses (%)	18.4%	23.4%	28.4%
Net Energy (MWh/yr)	213,045	181,816	152,960
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$52,103,621	$53,166,960	$54,230,299
Foundations	$9,233,587	$9,422,028	$9,610,469
Assembly & Checkout	$1,862,784	$1,900,800	$1,938,816
Electrical Infrastructure	$2,614,754	$2,668,116	$2,721,478
Sub-Station	$3,528,000	$3,600,000	$3,672,000
Overseas Shipping	$2,156,000	$2,200,000	$2,244,000
Legal Fees & Permitting	$427,135	$533,919	$667,398
General Capital Facilities			
Roads & Grading	$902,470	$920,888	$939,306
Control System	$620,928	$633,600	$646,272
Control Buildings	$155,232	$158,400	$161,568
Central Building	$87,030	$96,700	$120,875
Engineering & Overhead	$5,034,812	$5,144,428	$5,255,912
Project Contingency	$7,872,635	$8,044,584	$8,220,839
Initial Costs	$4,468,931	$4,552,859	$4,634,883
SUB-TOTAL	$91,067,919	$93,043,281	$95,064,116
TRANSMISSION			
Cost of Upgrade	$9,735,630	$9,934,316	$10,133,002
ANNUAL EXPENSES			
Variable O&M	$575,221	$545,449	$504,769
Fixed O&M	$653,400	$660,000	$666,600
Land Lease	$331,056	$348,480	$365,904
FIRST YEAR O&M	$1,559,677	$1,553,929	$1,537,273

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	3			Stage (current/future)	Future14
Resource (mph, avg)	23			Extent (# of units)	2
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	16,178	14,707	13,236
Expected Losses (%)	12.6%	17.6%	22.6%
Net Energy (MWh/yr)	14,135	12,115	10,241
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$2,530,238	$2,811,375	$3,233,081
Foundations	$252,249	$257,397	$262,545
Assembly & Checkout	$43,120	$44,000	$44,880
Electrical Infrastructure	$85,644	$87,392	$89,139
Sub-Station	$216,090	$220,500	$224,910
Overseas Shipping	$58,800	$60,000	$61,200
Legal Fees & Permitting	$284,689	$355,861	$444,827
General Capital Facilities			
Roads & Grading	$21,357	$21,793	$22,229
Control System	$23,050	$23,520	$23,990
Control Buildings	$5,762	$5,880	$5,998
Central Building	$11,378	$12,642	$15,803
Engineering & Overhead	$242,958	$273,025	$305,241
Project Contingency	$377,533	$417,338	$473,384
Initial Costs	$214,793	$232,950	$267,043
SUB-TOTAL	$4,367,661	$4,823,674	$5,474,269
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$37,401	$35,617	$33,121
Fixed O&M	$29,106	$17,640	$29,694
Land Lease	$4,028	$4,240	$4,452
FIRST YEAR O&M	$70,535	$57,497	$67,267

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	30			Stage (current/future)	Future14
Resource (mph, avg)	23			Extent (# of units)	20
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	161,779	147,072	132,364
Expected Losses (%)	18.9%	23.9%	28.9%
Net Energy (MWh/yr)	131,132	111,857	94,053
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$24,097,500	$26,775,000	$30,791,250
Foundations	$2,522,491	$2,573,970	$2,625,449
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$856,437	$873,915	$891,393
Sub-Station	$2,160,900	$2,205,000	$2,249,100
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$345,646	$432,057	$540,072
General Capital Facilities			
Roads & Grading	$162,989	$166,315	$169,641
Control System	$230,496	$235,200	$239,904
Control Buildings	$57,624	$58,800	$59,976
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$2,170,152	$2,411,852	$2,671,065
Project Contingency	$3,370,872	$3,686,688	$4,141,711
Initial Costs	$2,005,225	$2,208,918	$2,475,891
SUB-TOTAL	$39,084,821	$42,762,481	$48,034,709
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$346,975	$328,861	$304,169
Fixed O&M	$291,060	$176,400	$296,940
Land Lease	$40,280	$42,400	$44,520
FIRST YEAR O&M	$678,315	$547,661	$645,629

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	50			Stage (current/future)	Future14
Resource (mph, avg)	23			Extent (# of units)	33
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	266,935	242,668	218,401
Expected Losses (%)	18.9%	23.9%	28.9%
Net Energy (MWh/yr)	216,368	184,565	155,188
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$38,965,658	$43,295,175	$49,789,451
Foundations	$4,162,109	$4,247,051	$4,331,992
Assembly & Checkout	$711,480	$726,000	$740,520
Electrical Infrastructure	$1,413,121	$1,441,960	$1,470,799
Sub-Station	$3,601,500	$3,675,000	$3,748,500
Overseas Shipping	$970,200	$990,000	$1,009,800
Legal Fees & Permitting	$388,051	$485,064	$606,330
General Capital Facilities			
Roads & Grading	$265,278	$270,692	$276,106
Control System	$380,318	$388,080	$395,842
Control Buildings	$95,080	$97,020	$98,960
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$3,514,848	$3,899,757	$4,318,817
Project Contingency	$5,455,293	$5,961,056	$6,690,557
Initial Costs	$3,248,850	$3,549,037	$4,007,530
SUB-TOTAL	$63,257,076	$69,120,658	$77,603,662
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$572,510	$542,620	$501,879
Fixed O&M	$480,249	$291,060	$489,951
Land Lease	$66,462	$69,960	$73,458
FIRST YEAR O&M	$1,119,221	$903,640	$1,065,288

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	North Kohala	Project Code:	(leave blank)
Capacity (MW)	5			Stage (current/future)	Future14
Resource (mph, avg)	24			Extent (# of units)	3
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	28,012	25,466	22,919
Expected Losses (%)	12.6%	17.6%	22.6%
Net Energy (MWh/yr)	24,475	20,977	17,733
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$3,795,356	$4,217,063	$4,849,622
Foundations	$416,211	$424,705	$433,199
Assembly & Checkout	$64,680	$66,000	$67,320
Electrical Infrastructure	$128,466	$131,087	$133,709
Sub-Station	$360,150	$367,500	$374,850
Overseas Shipping	$88,200	$90,000	$91,800
Legal Fees & Permitting	$288,436	$360,545	$450,681
General Capital Facilities			
Roads & Grading	$32,598	$33,263	$33,928
Control System	$34,574	$35,280	$35,986
Control Buildings	$8,644	$8,820	$8,996
Central Building	$39,778	$44,198	$55,248
Engineering & Overhead	$359,905	$404,492	$448,083
Project Contingency	$561,700	$618,295	$698,342
Initial Costs	$326,546	$361,173	$403,669
SUB-TOTAL	$6,505,243	$7,162,421	$8,085,432
TRANSMISSION			
Cost of Upgrade	$389,425	$397,373	$405,320
ANNUAL EXPENSES			
Variable O&M	$64,761	$61,671	$57,349
Fixed O&M	$43,659	$26,460	$44,541
Land Lease	$18,126	$19,080	$20,034
FIRST YEAR O&M	$126,546	$107,211	$121,924

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	North Kohala	Project Code:	(leave blank)
Capacity (MW)	10			Stage (current/future)	Future14
Resource (mph, avg)	24			Extent (# of units)	6
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	56,024	50,931	45,838
Expected Losses (%)	13.5%	18.5%	23.5%
Net Energy (MWh/yr)	48,489	41,534	35,089
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$7,229,250	$8,032,500	$9,237,375
Foundations	$832,422	$849,410	$866,398
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$256,931	$262,175	$267,418
Sub-Station	$720,300	$735,000	$749,700
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$298,470	$373,087	$466,359
General Capital Facilities			
Roads & Grading	$59,575	$60,791	$62,007
Control System	$69,149	$70,560	$71,971
Control Buildings	$17,287	$17,640	$17,993
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$675,019	$756,555	$833,384
Project Contingency	$1,054,945	$1,156,448	$1,300,930
Initial Costs	$621,919	$737,310	$766,044
SUB-TOTAL	$12,226,317	$13,458,242	$15,076,277
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$128,301	$122,110	$113,477
Fixed O&M	$87,318	$52,920	$89,082
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$251,871	$213,190	$242,627

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Kahua Ranch	Project Code:	(leave blank)
Capacity (MW)	10			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	6
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	42,114	38,286	34,457
Expected Losses (%)	13.0%	18.0%	23.0%
Net Energy (MWh/yr)	36,628	31,384	26,522
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$7,229,250	$8,032,500	$9,237,375
Foundations	$756,747	$772,191	$787,635
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$256,931	$262,175	$267,418
Sub-Station	$720,300	$735,000	$749,700
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$298,301	$372,877	$466,096
General Capital Facilities			
Roads & Grading	$52,831	$53,909	$54,987
Control System	$69,149	$70,560	$71,971
Control Buildings	$17,287	$17,640	$17,993
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$669,710	$750,653	$827,852
Project Contingency	$1,046,156	$1,147,427	$1,291,773
Initial Costs	$612,421	$679,595	$757,397
SUB-TOTAL	$12,120,133	$13,301,293	$14,966,895
TRANSMISSION			
Cost of Upgrade	$865,389	$883,050	$900,711
ANNUAL EXPENSES			
Variable O&M	$96,917	$92,268	$85,774
Fixed O&M	$87,318	$52,920	$89,082
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$220,487	$183,348	$214,924

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Kauai	Location:	N. Hanapepe	Project Code:	(leave blank)
Capacity (MW)	10			Stage (current/future)	Future14
Resource (mph, avg)	18			Extent (# of units)	6
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	29,595	26,904	24,214
Expected Losses (%)	10.9%	15.9%	20.9%
Net Energy (MWh/yr)	26,369	22,627	19,154
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$7,229,250	$8,032,500	$9,237,375
Foundations	$832,422	$849,410	$866,398
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$342,575	$349,566	$356,557
Sub-Station	$720,300	$735,000	$749,700
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$298,681	$373,351	$466,689
General Capital Facilities			
Roads & Grading	$77,560	$79,143	$80,726
Control System	$69,149	$70,560	$71,971
Control Buildings	$17,287	$17,640	$17,993
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$681,029	$763,976	$839,647
Project Contingency	$1,065,930	$1,167,791	$1,312,375
Initial Costs	$609,364	$659,305	$755,324
SUB-TOTAL	$12,334,597	$13,505,008	$15,191,454
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$69,774	$66,524	$61,943
Fixed O&M	$87,318	$52,920	$89,082
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$193,344	$157,604	$191,093

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Kauai	Location:	Port Allen	Project Code:	(leave blank)
Capacity (MW)	5			Stage (current/future)	Future14
Resource (mph, avg)	16			Extent (# of units)	3
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	14,377	13,070	11,763
Expected Losses (%)	7.8%	12.8%	17.8%
Net Energy (MWh/yr)	13,251	11,393	9,666
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$3,795,356	$4,217,063	$4,849,622
Foundations	$378,374	$386,096	$393,817
Assembly & Checkout	$64,680	$66,000	$67,320
Electrical Infrastructure	$128,466	$131,087	$133,709
Sub-Station	$360,150	$367,500	$374,850
Overseas Shipping	$88,200	$90,000	$91,800
Legal Fees & Permitting	$288,352	$360,440	$450,550
General Capital Facilities			
Roads & Grading	$29,226	$29,822	$30,418
Control System	$34,574	$35,280	$35,986
Control Buildings	$8,644	$8,820	$8,996
Central Building	$39,778	$44,198	$55,248
Engineering & Overhead	$357,250	$401,541	$445,317
Project Contingency	$557,305	$613,785	$693,763
Initial Costs	$315,275	$342,158	$392,947
SUB-TOTAL	$6,445,629	$7,093,789	$8,024,343
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$35,063	$33,496	$31,259
Fixed O&M	$43,659	$26,460	$44,541
Land Lease	$6,042	$6,360	$6,678
FIRST YEAR O&M	$84,764	$66,316	$82,478

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Kaheawa Pastures	Project Code:	(leave blank)
Capacity (MW)	10 Expansion		Stage (current/future)		Future14
Resource (mph, avg)	21		Extent (# of units)		6
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	48,803	44,367	39,930
Expected Losses (%)	10.5%	15.5%	20.5%
Net Energy (MWh/yr)	43,658	37,471	31,727
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$7,229,250	$8,032,500	$9,237,375
Foundations	$832,422	$849,410	$866,398
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$342,575	$349,566	$356,557
Sub-Station	$0	$0	$0
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$296,845	$371,057	$463,821
General Capital Facilities			
Roads & Grading	$77,560	$79,143	$80,726
Control System	$0	$0	$0
Control Buildings	$0	$0	$0
Central Building	$0	$0	$0
Engineering & Overhead	$630,480	$699,557	$786,967
Project Contingency	$971,489	$1,069,323	$1,211,008
Initial Costs	$602,923	$651,810	$746,270
SUB-TOTAL	$11,289,304	$12,414,366	$14,067,363
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$115,520	$110,165	$102,607
Fixed O&M	$87,318	$52,920	$89,082
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$239,090	$201,245	$231,757

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	10			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	6
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	39,841	36,219	32,597
Expected Losses (%)	10.1%	15.1%	20.1%
Net Energy (MWh/yr)	35,815	30,748	26,043
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$7,229,250	$8,032,500	$9,237,375
Foundations	$756,747	$772,191	$787,635
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$256,931	$262,175	$267,418
Sub-Station	$720,300	$735,000	$749,700
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$298,301	$372,877	$466,096
General Capital Facilities			
Roads & Grading	$52,831	$53,909	$54,987
Control System	$69,149	$70,560	$71,971
Control Buildings	$17,287	$17,640	$17,993
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$669,710	$750,653	$827,852
Project Contingency	$1,046,156	$1,147,427	$1,291,773
Initial Costs	$611,883	$661,467	$757,010
SUB-TOTAL	$12,119,595	$13,283,165	$14,966,507
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$94,766	$90,399	$84,224
Fixed O&M	$87,318	$52,920	$89,082
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$218,336	$181,479	$213,374

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	30			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	20
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	132,802	120,729	108,656
Expected Losses (%)	16.2%	21.2%	26.2%
Net Energy (MWh/yr)	111,247	95,097	80,155
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$24,097,500	$26,775,000	$30,791,250
Foundations	$2,522,491	$2,573,970	$2,625,449
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$856,437	$873,915	$891,393
Sub-Station	$2,160,900	$2,205,000	$2,249,100
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$345,646	$432,057	$540,072
General Capital Facilities			
Roads & Grading	$162,989	$166,315	$169,641
Control System	$230,496	$235,200	$239,904
Control Buildings	$57,624	$58,800	$59,976
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$2,170,152	$2,411,852	$2,671,065
Project Contingency	$3,370,872	$3,686,688	$4,141,711
Initial Costs	$2,012,211	$2,239,876	$2,486,913
SUB-TOTAL	$39,091,807	$42,793,438	$48,045,732
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$294,359	$279,585	$259,220
Fixed O&M	$291,060	$176,400	$296,940
Land Lease	$120,840	$127,200	$133,560
FIRST YEAR O&M	$706,259	$583,185	$689,720

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	50			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	33
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	219,123	199,203	179,283
Expected Losses (%)	16.2%	21.2%	26.2%
Net Energy (MWh/yr)	183,557	156,910	132,255
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$38,965,658	$43,295,175	$49,789,451
Foundations	$4,162,109	$4,247,051	$4,331,992
Assembly & Checkout	$711,480	$726,000	$740,520
Electrical Infrastructure	$1,413,121	$1,441,960	$1,470,799
Sub-Station	$3,601,500	$3,675,000	$3,748,500
Overseas Shipping	$970,200	$990,000	$1,009,800
Legal Fees & Permitting	$388,051	$485,064	$606,330
General Capital Facilities			
Roads & Grading	$265,278	$270,692	$276,106
Control System	$380,318	$388,080	$395,842
Control Buildings	$95,080	$97,020	$98,960
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$3,514,848	$3,899,757	$4,318,817
Project Contingency	$5,455,293	$5,961,056	$6,690,557
Initial Costs	$3,260,377	$3,585,768	$4,025,717
SUB-TOTAL	$63,268,603	$69,157,388	$77,621,850
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$485,693	$461,316	$427,713
Fixed O&M	$480,249	$291,060	$489,951
Land Lease	$199,386	$209,880	$220,374
FIRST YEAR O&M	$1,165,328	$962,256	$1,138,038

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Puunene	Project Code:	(leave blank)
Capacity (MW)	10			Stage (current/future)	Future14
Resource (mph, avg)	16			Extent (# of units)	6
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	29,152	26,502	23,851
Expected Losses (%)	10.1%	15.1%	20.1%
Net Energy (MWh/yr)	26,206	22,499	19,056
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$7,229,250	$8,032,500	$9,237,375
Foundations	$832,422	$849,410	$866,398
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$256,931	$262,175	$267,418
Sub-Station	$720,300	$735,000	$749,700
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$298,470	$373,087	$466,359
General Capital Facilities			
Roads & Grading	$59,575	$60,791	$62,007
Control System	$69,149	$70,560	$71,971
Control Buildings	$17,287	$17,640	$17,993
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$675,019	$756,555	$833,384
Project Contingency	$1,054,945	$1,156,448	$1,300,930
Initial Costs	$601,137	$650,730	$746,404
SUB-TOTAL	$12,205,535	$13,371,662	$15,056,637
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$69,341	$66,146	$61,628
Fixed O&M	$87,318	$52,920	$89,082
Land Lease	$12,084	$12,720	$13,356
FIRST YEAR O&M	$168,743	$131,786	$164,066

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Puunene	Project Code:	(leave blank)
Capacity (MW)	30			Stage (current/future)	Future14
Resource (mph, avg)	16			Extent (# of units)	20
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	97,172	88,338	79,505
Expected Losses (%)	16.2%	21.2%	26.2%
Net Energy (MWh/yr)	81,400	69,583	58,650
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$24,097,500	$26,775,000	$30,791,250
Foundations	$2,774,740	$2,831,367	$2,887,994
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$856,437	$873,915	$891,393
Sub-Station	$2,160,900	$2,205,000	$2,249,100
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$346,207	$432,758	$540,948
General Capital Facilities			
Roads & Grading	$185,470	$189,255	$193,040
Control System	$230,496	$235,200	$239,904
Control Buildings	$57,624	$58,800	$59,976
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$2,187,849	$2,431,524	$2,689,504
Project Contingency	$3,400,171	$3,716,759	$4,172,237
Initial Costs	$1,977,834	$2,205,544	$2,453,003
SUB-TOTAL	$39,379,716	$43,089,888	$48,347,607
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$215,385	$204,575	$189,673
Fixed O&M	$291,060	$176,400	$296,940
Land Lease	$40,280	$42,400	$44,520
FIRST YEAR O&M	$546,725	$423,375	$531,133

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kaena Point	Project Code:	(leave blank)
Capacity (MW)	3			Stage (current/future)	Future14
Resource (mph, avg)	18			Extent (# of units)	2
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	11,062	10,057	9,051
Expected Losses (%)	9.2%	14.2%	19.2%
Net Energy (MWh/yr)	10,044	8,628	7,313
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$2,530,238	$2,811,375	$3,233,081
Foundations	$252,249	$257,397	$262,545
Assembly & Checkout	$43,120	$44,000	$44,880
Electrical Infrastructure	$114,192	$116,522	$118,852
Sub-Station	$216,090	$220,500	$224,910
Overseas Shipping	$58,800	$60,000	$61,200
Legal Fees & Permitting	$284,758	$355,947	$444,934
General Capital Facilities			
Roads & Grading	$26,603	$27,146	$27,689
Control System	$23,050	$23,520	$23,990
Control Buildings	$5,762	$5,880	$5,998
Central Building	$11,378	$12,642	$15,803
Engineering & Overhead	$244,961	$275,445	$307,328
Project Contingency	$381,120	$421,037	$477,121
Initial Costs	$212,764	$231,079	$265,380
SUB-TOTAL	$4,405,084	$4,862,490	$5,513,712
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$26,576	$25,366	$23,649
Fixed O&M	$29,106	$17,640	$29,694
Land Lease	$4,028	$4,240	$4,452
FIRST YEAR O&M	$59,710	$47,246	$57,795

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kaena Point	Project Code:	(leave blank)
Capacity (MW)	15		Stage (current/future)		Future14
Resource (mph, avg)	18		Extent (# of units)		10
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	55,312	50,284	45,255
Expected Losses (%)	12.3%	17.3%	22.3%
Net Energy (MWh/yr)	48,528	41,602	35,179
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$12,048,750	$13,387,500	$15,395,625
Foundations	$1,261,245	$1,286,985	$1,312,725
Assembly & Checkout	$215,600	$220,000	$224,400
Electrical Infrastructure	$570,958	$582,610	$594,262
Sub-Station	$1,080,450	$1,102,500	$1,124,550
Overseas Shipping	$294,000	$300,000	$306,000
Legal Fees & Permitting	$312,068	$390,085	$487,607
General Capital Facilities			
Roads & Grading	$110,533	$112,788	$115,044
Control System	$115,248	$117,600	$119,952
Control Buildings	$28,812	$29,400	$29,988
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$1,104,815	$1,233,696	$1,361,162
Project Contingency	$1,722,777	$1,885,793	$2,118,977
Initial Costs	$998,415	$1,112,901	$1,237,478
SUB-TOTAL	$19,948,960	$21,856,626	$24,546,227
TRANSMISSION			
Cost of Upgrade	$1,622,605	$1,655,719	$1,688,834
ANNUAL EXPENSES			
Variable O&M	$128,404	$122,310	$113,769
Fixed O&M	$145,530	$88,200	$148,470
Land Lease	$20,140	$21,200	$22,260
FIRST YEAR O&M	$294,074	$231,710	$284,499

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	30			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	20
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	117,065	106,423	95,781
Expected Losses (%)	15.8%	20.8%	25.8%
Net Energy (MWh/yr)	98,585	84,302	71,083
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$24,097,500	$26,775,000	$30,791,250
Foundations	$2,774,740	$2,831,367	$2,887,994
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$970,628	$990,437	$1,010,246
Sub-Station	$2,160,900	$2,205,000	$2,249,100
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$346,489	$433,111	$541,388
General Capital Facilities			
Roads & Grading	$209,450	$213,724	$217,999
Control System	$230,496	$235,200	$239,904
Control Buildings	$57,624	$58,800	$59,976
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$2,195,862	$2,441,418	$2,697,854
Project Contingency	$3,414,818	$3,731,882	$4,187,497
Initial Costs	$2,012,111	$2,194,029	$2,488,200
SUB-TOTAL	$39,575,106	$43,244,734	$48,550,666
TRANSMISSION			
Cost of Upgrade	$973,563	$993,432	$1,013,300
ANNUAL EXPENSES			
Variable O&M	$260,857	$247,848	$229,882
Fixed O&M	$291,060	$176,400	$296,940
Land Lease	$120,840	$127,200	$133,560
FIRST YEAR O&M	$672,757	$551,448	$660,382

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	50			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	33
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	193,158	175,598	158,038
Expected Losses (%)	15.8%	20.8%	25.8%
Net Energy (MWh/yr)	162,666	139,098	117,287
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$38,965,658	$43,295,175	$49,789,451
Foundations	$4,578,320	$4,671,756	$4,765,191
Assembly & Checkout	$711,480	$726,000	$740,520
Electrical Infrastructure	$1,601,537	$1,634,221	$1,666,905
Sub-Station	$3,601,500	$3,675,000	$3,748,500
Overseas Shipping	$970,200	$990,000	$1,009,800
Legal Fees & Permitting	$389,442	$486,802	$608,503
General Capital Facilities			
Roads & Grading	$341,939	$348,917	$355,896
Control System	$380,318	$388,080	$395,842
Control Buildings	$95,080	$97,020	$98,960
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$3,557,270	$3,948,542	$4,363,021
Project Contingency	$5,527,803	$6,035,628	$6,766,105
Initial Costs	$3,260,210	$3,564,538	$4,027,841
SUB-TOTAL	$64,066,046	$69,956,445	$78,454,992
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$430,414	$408,949	$379,305
Fixed O&M	$480,249	$291,060	$489,951
Land Lease	$199,386	$209,880	$220,374
FIRST YEAR O&M	$1,110,049	$909,889	$1,089,630

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	80			Stage (current/future)	Future14
Resource (mph, avg)	19			Extent (# of units)	53
Project Life (years)	30			Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	310,223	282,021	253,819
Expected Losses (%)	15.8%	20.8%	25.8%
Net Energy (MWh/yr)	261,252	223,400	188,369
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$62,581,208	$69,534,675	$79,964,876
Foundations	$7,353,060	$7,503,123	$7,653,185
Assembly & Checkout	$1,142,680	$1,166,000	$1,189,320
Electrical Infrastructure	$2,572,165	$2,624,658	$2,677,151
Sub-Station	$5,762,400	$5,880,000	$5,997,600
Overseas Shipping	$1,558,200	$1,590,000	$1,621,800
Legal Fees & Permitting	$457,058	$571,323	$714,154
General Capital Facilities			
Roads & Grading	$545,769	$556,907	$568,045
Control System	$610,814	$623,280	$635,746
Control Buildings	$152,704	$155,820	$158,936
Central Building	$85,289	$94,766	$118,458
Engineering & Overhead	$5,699,874	$6,321,039	$6,987,266
Project Contingency	$8,852,122	$9,662,159	$10,828,654
Initial Costs	$5,231,189	$5,846,765	$6,461,732
SUB-TOTAL	$102,604,532	$112,130,514	$125,576,922
TRANSMISSION			
Cost of Upgrade	$9,735,630	$9,934,316	$10,133,002
ANNUAL EXPENSES			
Variable O&M	$691,272	$656,797	$609,186
Fixed O&M	$771,309	$467,460	$786,891
Land Lease	$320,226	$337,080	$353,934
FIRST YEAR O&M	$1,782,807	$1,461,337	$1,750,011

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	3		Stage (current/future)		Future20
Resource (mph, avg)	23		Extent (# of units)		2
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	18,605	16,913	15,222
Expected Losses (%)	12.6%	17.6%	22.6%
Net Energy (MWh/yr)	16,255	13,932	11,778
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$2,403,726	$2,670,806	$3,071,427
Foundations	$239,637	$244,527	$249,418
Assembly & Checkout	$43,120	$44,000	$44,880
Electrical Infrastructure	$83,931	$85,644	$87,357
Sub-Station	$211,768	$216,090	$220,412
Overseas Shipping	$58,800	$60,000	$61,200
Legal Fees & Permitting	$284,368	$355,460	$444,325
General Capital Facilities			
Roads & Grading	$21,357	$21,793	$22,229
Control System	$22,589	$23,050	$23,511
Control Buildings	$5,647	$5,762	$5,878
Central Building	$11,150	$12,389	$15,486
Engineering & Overhead	$232,774	$261,766	$292,531
Project Contingency	$361,887	$400,129	$453,865
Initial Costs	$206,584	$226,629	$256,214
SUB-TOTAL	$4,187,338	$4,628,046	$5,248,732
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$42,151	$40,140	$37,327
Fixed O&M	$28,524	$28,812	$29,100
Land Lease	$4,028	$4,240	$4,452
FIRST YEAR O&M	$74,703	$73,192	$70,879

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		Future20
Resource (mph, avg)	23		Extent (# of units)		20
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	186,046	169,132	152,219
Expected Losses (%)	18.9%	23.9%	28.9%
Net Energy (MWh/yr)	150,802	128,636	108,161
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$22,892,625	$25,436,250	$29,251,688
Foundations	$2,396,366	$2,445,272	$2,494,177
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$839,308	$856,437	$873,565
Sub-Station	$2,117,682	$2,160,900	$2,204,118
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$342,572	$428,215	$535,269
General Capital Facilities			
Roads & Grading	$162,989	$166,315	$169,641
Control System	$225,886	$230,496	$235,106
Control Buildings	$56,472	$57,624	$58,776
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$2,072,543	$2,304,007	$2,549,373
Project Contingency	$3,220,923	$3,521,839	$3,954,860
Initial Costs	$1,926,505	$2,149,539	$2,372,149
SUB-TOTAL	$37,356,654	$40,889,764	$45,875,611
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$391,041	$370,626	$342,798
Fixed O&M	$285,239	$288,120	$291,001
Land Lease	$40,280	$42,400	$44,520
FIRST YEAR O&M	$716,560	$701,146	$678,319

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Lalamilo Wells	Project Code:	(leave blank)
Capacity (MW)	50		Stage (current/future)		Future20
Resource (mph, avg)	23		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	306,975	279,068	251,162
Expected Losses (%)	18.9%	23.9%	28.9%
Net Energy (MWh/yr)	248,823	212,249	178,466
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$37,017,375	$41,130,416	$47,299,979
Foundations	$3,954,004	$4,034,698	$4,115,392
Assembly & Checkout	$711,480	$726,000	$740,520
Electrical Infrastructure	$1,384,858	$1,413,121	$1,441,383
Sub-Station	$3,529,470	$3,601,500	$3,673,530
Overseas Shipping	$970,200	$990,000	$1,009,800
Legal Fees & Permitting	$383,069	$478,837	$598,546
General Capital Facilities			
Roads & Grading	$265,278	$270,692	$276,106
Control System	$372,712	$380,318	$387,925
Control Buildings	$93,178	$95,080	$96,981
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$3,356,532	$3,724,947	$4,121,540
Project Contingency	$5,212,174	$5,693,848	$6,387,779
Initial Costs	$3,121,754	$3,454,167	$3,839,931
SUB-TOTAL	$60,455,668	$66,086,494	$74,105,500
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$645,218	$611,533	$565,617
Fixed O&M	$470,644	$475,398	$480,152
Land Lease	$66,462	$69,960	$73,458
FIRST YEAR O&M	$1,182,324	$1,156,891	$1,119,227

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	North Kohala	Project Code:	(leave blank)
Capacity (MW)	5		Stage (current/future)		Future20
Resource (mph, avg)	24		Extent (# of units)		3
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	32,214	29,286	26,357
Expected Losses (%)	12.6%	17.6%	22.6%
Net Energy (MWh/yr)	28,146	24,123	20,393
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$3,605,588	$4,006,209	$4,607,141
Foundations	$395,400	$403,470	$411,539
Assembly & Checkout	$64,680	$66,000	$67,320
Electrical Infrastructure	$125,896	$128,466	$131,035
Sub-Station	$352,947	$360,150	$367,353
Overseas Shipping	$88,200	$90,000	$91,800
Legal Fees & Permitting	$287,948	$359,935	$449,919
General Capital Facilities			
Roads & Grading	$32,598	$33,263	$33,928
Control System	$33,883	$34,574	$35,266
Control Buildings	$8,471	$8,644	$8,816
Central Building	$38,983	$43,314	$54,143
Engineering & Overhead	$344,446	$387,382	$428,827
Project Contingency	$537,904	$592,141	$668,709
Initial Costs	$314,446	$351,889	$387,601
SUB-TOTAL	$6,231,390	$6,865,436	$7,743,397
TRANSMISSION			
Cost of Upgrade	$389,425	$397,373	$405,320
ANNUAL EXPENSES			
Variable O&M	$72,985	$69,504	$64,632
Fixed O&M	$42,786	$43,218	$43,650
Land Lease	$18,126	$19,080	$20,034
FIRST YEAR O&M	$133,897	$131,802	$128,316

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	North Kohala	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		Future20
Resource (mph, avg)	24		Extent (# of units)		6
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	64,428	58,571	52,714
Expected Losses (%)	13.5%	18.5%	23.5%
Net Energy (MWh/yr)	55,762	47,764	40,352
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,867,788	$7,630,875	$8,775,506
Foundations	$790,801	$806,940	$823,078
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$251,792	$256,931	$262,070
Sub-Station	$705,894	$720,300	$734,706
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$297,534	$371,918	$464,897
General Capital Facilities			
Roads & Grading	$59,575	$60,791	$62,007
Control System	$67,766	$69,149	$70,532
Control Buildings	$16,941	$17,287	$17,633
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$645,370	$723,734	$796,495
Project Contingency	$1,009,280	$1,106,280	$1,244,125
Initial Costs	$598,943	$720,107	$735,485
SUB-TOTAL	$11,701,028	$12,889,182	$14,420,862
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$144,596	$137,618	$127,889
Fixed O&M	$85,572	$86,436	$87,300
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$266,419	$262,214	$255,257

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Hawaii	Location:	Kahua Ranch	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		6
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	48,432	44,029	39,626
Expected Losses (%)	13.0%	18.0%	23.0%
Net Energy (MWh/yr)	42,122	36,091	30,501
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,867,788	$7,630,875	$8,775,506
Foundations	$718,910	$733,581	$748,253
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$251,792	$256,931	$262,070
Sub-Station	$705,894	$720,300	$734,706
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$297,374	$371,717	$464,647
General Capital Facilities			
Roads & Grading	$52,831	$53,909	$54,987
Control System	$67,766	$69,149	$70,532
Control Buildings	$16,941	$17,287	$17,633
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$640,326	$718,103	$791,240
Project Contingency	$1,000,897	$1,097,672	$1,235,390
Initial Costs	$588,524	$661,523	$726,037
SUB-TOTAL	$11,598,386	$12,735,919	$14,315,329
TRANSMISSION			
Cost of Upgrade	$865,389	$883,050	$900,711
ANNUAL EXPENSES			
Variable O&M	$109,226	$103,986	$96,667
Fixed O&M	$85,572	$86,436	$87,300
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$231,049	$228,582	$224,035

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Kauai	Location:	N. Hanapepe	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		Future20
Resource (mph, avg)	18		Extent (# of units)		6
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	34,034	30,940	27,846
Expected Losses (%)	10.9%	15.9%	20.9%
Net Energy (MWh/yr)	30,325	26,021	22,027
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,867,788	$7,630,875	$8,775,506
Foundations	$790,801	$806,940	$823,078
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$335,723	$342,575	$349,426
Sub-Station	$705,894	$720,300	$734,706
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$297,742	$372,178	$465,222
General Capital Facilities			
Roads & Grading	$77,560	$79,143	$80,726
Control System	$67,766	$69,149	$70,532
Control Buildings	$16,941	$17,287	$17,633
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$651,260	$731,032	$802,633
Project Contingency	$1,020,082	$1,117,435	$1,255,379
Initial Costs	$584,495	$640,302	$723,093
SUB-TOTAL	$11,805,395	$12,932,086	$14,532,263
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$78,635	$74,972	$69,810
Fixed O&M	$85,572	$86,436	$87,300
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$200,459	$199,568	$197,178

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Kauai	Location:	Port Allen	Project Code:	(leave blank)
Capacity (MW)	5		Stage (current/future)		Future20
Resource (mph, avg)	16		Extent (# of units)		3
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	16,533	15,030	13,527
Expected Losses (%)	7.8%	12.8%	17.8%
Net Energy (MWh/yr)	15,239	13,102	11,116
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$3,605,588	$4,006,209	$4,607,141
Foundations	$359,455	$366,791	$374,127
Assembly & Checkout	$64,680	$66,000	$67,320
Electrical Infrastructure	$125,896	$128,466	$131,035
Sub-Station	$352,947	$360,150	$367,353
Overseas Shipping	$88,200	$90,000	$91,800
Legal Fees & Permitting	$287,868	$359,835	$449,794
General Capital Facilities			
Roads & Grading	$29,226	$29,822	$30,418
Control System	$33,883	$34,574	$35,266
Control Buildings	$8,471	$8,644	$8,816
Central Building	$38,983	$43,314	$54,143
Engineering & Overhead	$341,924	$384,566	$426,200
Project Contingency	$533,712	$587,837	$664,341
Initial Costs	$302,269	$332,019	$376,091
SUB-TOTAL	$6,173,102	$6,798,227	$7,683,844
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$39,516	$37,750	$35,229
Fixed O&M	$42,786	$43,218	$43,650
Land Lease	$6,042	$6,360	$6,678
FIRST YEAR O&M	$88,344	$87,328	$85,557

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		6
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	45,817	41,651	37,486
Expected Losses (%)	10.1%	15.1%	20.1%
Net Energy (MWh/yr)	41,187	35,360	29,950
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,867,788	$7,630,875	$8,775,506
Foundations	$718,910	$733,581	$748,253
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$251,792	$256,931	$262,070
Sub-Station	$705,894	$720,300	$734,706
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$297,374	$371,717	$464,647
General Capital Facilities			
Roads & Grading	$52,831	$53,909	$54,987
Control System	$67,766	$69,149	$70,532
Control Buildings	$16,941	$17,287	$17,633
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$640,326	$718,103	$791,240
Project Contingency	$1,000,897	$1,097,672	$1,235,390
Initial Costs	$587,918	$643,335	$725,601
SUB-TOTAL	$11,597,780	$12,717,731	$14,314,892
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$106,802	$101,880	$94,921
Fixed O&M	$85,572	$86,436	$87,300
Land Lease	$36,252	$38,160	$40,068
FIRST YEAR O&M	$228,625	$226,476	$222,289

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		20
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	152,722	138,838	124,954
Expected Losses (%)	16.2%	21.2%	26.2%
Net Energy (MWh/yr)	127,934	109,362	92,178
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$22,892,625	$25,436,250	$29,251,688
Foundations	$2,396,366	$2,445,272	$2,494,177
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$839,308	$856,437	$873,565
Sub-Station	$2,117,682	$2,160,900	$2,204,118
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$342,572	$428,215	$535,269
General Capital Facilities			
Roads & Grading	$162,989	$166,315	$169,641
Control System	$225,886	$230,496	$235,106
Control Buildings	$56,472	$57,624	$58,776
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$2,072,543	$2,304,007	$2,549,373
Project Contingency	$3,220,923	$3,521,839	$3,954,860
Initial Costs	$1,931,820	$2,178,932	$2,381,744
SUB-TOTAL	$37,361,969	$40,919,156	$45,885,207
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$331,743	$315,093	$292,141
Fixed O&M	$285,239	$288,120	$291,001
Land Lease	$120,840	$127,200	$133,560
FIRST YEAR O&M	$737,822	$730,413	$716,702

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	NW Haleakala	Project Code:	(leave blank)
Capacity (MW)	50		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	251,992	229,083	206,175
Expected Losses (%)	16.2%	21.2%	26.2%
Net Energy (MWh/yr)	211,091	180,447	152,093
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$37,017,375	$41,130,416	$47,299,979
Foundations	$3,954,004	$4,034,698	$4,115,392
Assembly & Checkout	$711,480	$726,000	$740,520
Electrical Infrastructure	$1,384,858	$1,413,121	$1,441,383
Sub-Station	$3,529,470	$3,601,500	$3,673,530
Overseas Shipping	$970,200	$990,000	$1,009,800
Legal Fees & Permitting	$383,069	$478,837	$598,546
General Capital Facilities			
Roads & Grading	$265,278	$270,692	$276,106
Control System	$372,712	$380,318	$387,925
Control Buildings	$93,178	$95,080	$96,981
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$3,356,532	$3,724,947	$4,121,540
Project Contingency	$5,212,174	$5,693,848	$6,387,779
Initial Costs	$3,130,524	$3,488,315	$3,855,764
SUB-TOTAL	$60,464,438	$66,120,643	$74,121,333
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$547,376	$519,903	$482,032
Fixed O&M	$470,644	$475,398	$480,152
Land Lease	$199,386	$209,880	$220,374
FIRST YEAR O&M	$1,217,406	$1,205,181	$1,182,558

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Puunene	Project Code:	(leave blank)
Capacity (MW)	10		Stage (current/future)		Future20
Resource (mph, avg)	16		Extent (# of units)		6
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	33,524	30,477	27,429
Expected Losses (%)	10.1%	15.1%	20.1%
Net Energy (MWh/yr)	30,137	25,873	21,915
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$6,867,788	$7,630,875	$8,775,506
Foundations	$790,801	$806,940	$823,078
Assembly & Checkout	$129,360	$132,000	$134,640
Electrical Infrastructure	$251,792	$256,931	$262,070
Sub-Station	$705,894	$720,300	$734,706
Overseas Shipping	$176,400	$180,000	$183,600
Legal Fees & Permitting	$297,534	$371,918	$464,897
General Capital Facilities			
Roads & Grading	$59,575	$60,791	$62,007
Control System	$67,766	$69,149	$70,532
Control Buildings	$16,941	$17,287	$17,633
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$645,370	$723,734	$796,495
Project Contingency	$1,009,280	$1,106,280	$1,244,125
Initial Costs	$576,289	$631,751	$714,198
SUB-TOTAL	$11,678,374	$12,800,826	$14,399,576
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$78,148	$74,546	$69,454
Fixed O&M	$85,572	$86,436	$87,300
Land Lease	$12,084	$12,720	$13,356
FIRST YEAR O&M	$175,803	$173,702	$170,111

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Maui	Location:	Puunene	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		Future20
Resource (mph, avg)	16		Extent (# of units)		20
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	111,748	101,589	91,430
Expected Losses (%)	16.2%	21.2%	26.2%
Net Energy (MWh/yr)	93,610	80,021	67,447
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$22,892,625	$25,436,250	$29,251,688
Foundations	$2,636,003	$2,689,799	$2,743,595
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$839,308	$856,437	$873,565
Sub-Station	$2,117,682	$2,160,900	$2,204,118
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$343,107	$428,884	$536,105
General Capital Facilities			
Roads & Grading	$185,470	$189,255	$193,040
Control System	$225,886	$230,496	$235,106
Control Buildings	$56,472	$57,624	$58,776
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$2,089,355	$2,322,776	$2,566,891
Project Contingency	$3,248,869	$3,550,529	$3,983,977
Initial Costs	$1,894,682	$2,141,961	$2,345,363
SUB-TOTAL	$37,632,242	$41,197,781	$46,169,112
TRANSMISSION			
Cost of Upgrade	$3,245,210	$3,311,439	$3,377,667
ANNUAL EXPENSES			
Variable O&M	$242,739	$230,556	$213,762
Fixed O&M	$285,239	$288,120	$291,001
Land Lease	$40,280	$42,400	$44,520
FIRST YEAR O&M	$568,258	$561,076	$549,283

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kaena Point	Project Code:	(leave blank)
Capacity (MW)	3		Stage (current/future)		Future20
Resource (mph, avg)	18		Extent (# of units)		2
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	12,722	11,565	10,409
Expected Losses (%)	9.2%	14.2%	19.2%
Net Energy (MWh/yr)	11,550	9,922	8,409
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$2,403,726	$2,670,806	$3,071,427
Foundations	$239,637	$244,527	$249,418
Assembly & Checkout	$43,120	$44,000	$44,880
Electrical Infrastructure	$111,908	$114,192	$116,475
Sub-Station	$211,768	$216,090	$220,412
Overseas Shipping	$58,800	$60,000	$61,200
Legal Fees & Permitting	$284,436	$355,545	$444,431
General Capital Facilities			
Roads & Grading	$26,603	$27,146	$27,689
Control System	$22,589	$23,050	$23,511
Control Buildings	$5,647	$5,762	$5,878
Central Building	$11,150	$12,389	$15,486
Engineering & Overhead	$234,738	$264,145	$294,577
Project Contingency	$365,412	$403,765	$457,538
Initial Costs	$204,200	$224,420	$254,239
SUB-TOTAL	$4,223,732	$4,665,838	$5,287,160
TRANSMISSION			
Cost of Upgrade	$0	$0	$0
ANNUAL EXPENSES			
Variable O&M	$29,951	$28,587	$26,652
Fixed O&M	$28,524	$28,812	$29,100
Land Lease	$4,028	$4,240	$4,452
FIRST YEAR O&M	$62,503	$61,639	$60,204

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kaena Point	Project Code:	(leave blank)
Capacity (MW)	15		Stage (current/future)		Future20
Resource (mph, avg)	18		Extent (# of units)		10
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	63,609	57,826	52,044
Expected Losses (%)	12.3%	17.3%	22.3%
Net Energy (MWh/yr)	55,807	47,842	40,456
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$11,446,313	$12,718,125	$14,625,844
Foundations	$1,198,183	$1,222,636	$1,247,088
Assembly & Checkout	$215,600	$220,000	$224,400
Electrical Infrastructure	$559,539	$570,958	$582,377
Sub-Station	$1,058,841	$1,080,450	$1,102,059
Overseas Shipping	$294,000	$300,000	$306,000
Legal Fees & Permitting	$310,524	$388,155	$485,193
General Capital Facilities			
Roads & Grading	$110,533	$112,788	$115,044
Control System	$112,943	$115,248	$117,553
Control Buildings	$28,236	$28,812	$29,388
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$1,055,810	$1,179,503	$1,300,107
Project Contingency	$1,647,410	$1,802,955	$2,025,114
Initial Costs	$957,549	$1,081,797	$1,184,307
SUB-TOTAL	$19,079,064	$20,914,297	$23,460,564
TRANSMISSION			
Cost of Upgrade	$1,622,605	$1,655,719	$1,688,834
ANNUAL EXPENSES			
Variable O&M	$144,712	$137,843	$128,217
Fixed O&M	$142,619	$144,060	$145,501
Land Lease	$20,140	$21,200	$22,260
FIRST YEAR O&M	$307,471	$303,103	$295,978

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	30		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		20
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	134,625	122,387	110,148
Expected Losses (%)	15.8%	20.8%	25.8%
Net Energy (MWh/yr)	113,373	96,947	81,745
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$22,892,625	$25,436,250	$29,251,688
Foundations	$2,636,003	$2,689,799	$2,743,595
Assembly & Checkout	$431,200	$440,000	$448,800
Electrical Infrastructure	$951,216	$970,628	$990,041
Sub-Station	$2,117,682	$2,160,900	$2,204,118
Overseas Shipping	$588,000	$600,000	$612,000
Legal Fees & Permitting	$343,385	$429,231	$536,538
General Capital Facilities			
Roads & Grading	$209,450	$213,724	$217,999
Control System	$225,886	$230,496	$235,106
Control Buildings	$56,472	$57,624	$58,776
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$2,097,208	$2,332,507	$2,575,075
Project Contingency	$3,263,271	$3,565,403	$3,998,982
Initial Costs	$1,930,357	$2,131,773	$2,381,789
SUB-TOTAL	$37,826,337	$41,351,205	$46,370,595
TRANSMISSION			
Cost of Upgrade	$973,563	$993,432	$1,013,300
ANNUAL EXPENSES			
Variable O&M	$293,986	$279,325	$259,077
Fixed O&M	$285,239	$288,120	$291,001
Land Lease	$120,840	$127,200	$133,560
FIRST YEAR O&M	$700,065	$694,645	$683,638

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	50		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		33
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	222,132	201,938	181,744
Expected Losses (%)	15.8%	20.8%	25.8%
Net Energy (MWh/yr)	187,066	159,963	134,880
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$37,017,375	$41,130,416	$47,299,979
Foundations	$4,349,404	$4,438,168	$4,526,931
Assembly & Checkout	$711,480	$726,000	$740,520
Electrical Infrastructure	$1,569,506	$1,601,537	$1,633,567
Sub-Station	$3,529,470	$3,601,500	$3,673,530
Overseas Shipping	$970,200	$990,000	$1,009,800
Legal Fees & Permitting	$384,410	$480,512	$600,640
General Capital Facilities			
Roads & Grading	$341,939	$348,917	$355,896
Control System	$372,712	$380,318	$387,925
Control Buildings	$93,178	$95,080	$96,981
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$3,397,229	$3,771,972	$4,163,948
Project Contingency	$5,282,049	$5,765,729	$6,460,580
Initial Costs	$3,128,111	$3,464,921	$3,855,837
SUB-TOTAL	$61,230,646	$66,887,941	$74,922,222
TRANSMISSION			
Cost of Upgrade	$2,163,473	$2,207,626	$2,251,778
ANNUAL EXPENSES			
Variable O&M	$485,077	$460,886	$427,476
Fixed O&M	$470,644	$475,398	$480,152
Land Lease	$199,386	$209,880	$220,374
FIRST YEAR O&M	$1,155,107	$1,146,164	$1,128,002

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Wind

Island	Oahu	Location:	Kahuku	Project Code:	(leave blank)
Capacity (MW)	80		Stage (current/future)		Future20
Resource (mph, avg)	19		Extent (# of units)		53
Project Life (years)	30		Construction Time (years)		1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	356,757	324,325	291,892
Expected Losses (%)	15.8%	20.8%	25.8%
Net Energy (MWh/yr)	300,439	256,910	216,625
CAPITAL COSTS			
Process Capital			
Turbines & Towers	$59,452,147	$66,057,941	$75,966,632
Foundations	$6,985,407	$7,127,966	$7,270,526
Assembly & Checkout	$1,142,680	$1,166,000	$1,189,320
Electrical Infrastructure	$2,520,722	$2,572,165	$2,623,608
Sub-Station	$5,647,152	$5,762,400	$5,877,648
Overseas Shipping	$1,558,200	$1,590,000	$1,621,800
Legal Fees & Permitting	$448,980	$561,224	$701,531
General Capital Facilities			
Roads & Grading	$545,769	$556,907	$568,045
Control System	$598,598	$610,814	$623,031
Control Buildings	$149,650	$152,704	$155,758
Central Building	$83,584	$92,871	$116,088
Engineering & Overhead	$5,442,870	$6,037,569	$6,667,575
Project Contingency	$8,457,576	$9,228,856	$10,338,156
Initial Costs	$5,019,058	$5,686,805	$6,185,521
SUB-TOTAL	$98,052,391	$107,204,223	$119,905,239
TRANSMISSION			
Cost of Upgrade	$9,735,630	$9,934,316	$10,133,002
ANNUAL EXPENSES			
Variable O&M	$779,063	$740,210	$686,553
Fixed O&M	$755,883	$763,518	$771,153
Land Lease	$320,226	$337,080	$353,934
FIRST YEAR O&M	$1,855,172	$1,840,808	$1,811,640

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island	Hawaii	Location:	N. Kohala	Project Code:	(leave blank)

Capacity (MW)	5	Stage (current/future)	Current: Year 2004
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	48,400
Project Life (years)	30	Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	13,582	11,813	10,635
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	13,449	11,695	10,525
CAPITAL COSTS			
Process Capital			
PV Modules	$10,530,000	$11,700,000	$12,285,000
Array Structure & Foundations	$2,865,347	$3,016,155	$3,166,963
Power Condtioning Units	$911,625	$1,402,500	$1,472,625
Electrical & SCADA	$1,992,859	$2,012,989	$2,033,119
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$180,983	$190,508	$200,034
Legal Fees & Permitting	$568,589	$710,736	$888,420
General Facilities			
Roads and Grading	$337,872	$375,414	$412,955
Buildings and Fencing	$125,727	$139,697	$153,666
Engineering & Overhead	$1,932,505	$1,932,505	$1,932,505
Project Contingency	$2,177,267	$2,177,267	$2,177,267
Initial Costs	$294,148	$294,148	$294,148
SUB-TOTAL	$22,194,478	$24,244,082	$25,323,473
TRANSMISSION			
Cost of Upgrade	$361,000	$380,000	$399,000
ANNUAL EXPENSES			
Variable O&M	$16,578	$18,420	$20,262
Fixed O&M	$23,156	$24,375	$25,594
Land Lease	$8,049	$8,472	$8,896
FIRST YEAR O&M	$47,783	$51,267	$54,751

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island	Oahu	Location:	Pearl Harbor	Project Code:	(leave blank)

Capacity (MW)	5	Stage (current/future)	Current: Year 2004
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	48,400
Project Life (years)	30	Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	11,912	10,360	9,327
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	11,795	10,257	9,231
CAPITAL COSTS			
Process Capital			
PV Modules	$10,530,000	$11,700,000	$12,285,000
Array Structure & Foundations	$2,865,347	$3,016,155	$3,166,963
Power Condtioning Units	$911,625	$1,402,500	$1,472,625
Electrical & SCADA	$1,992,859	$2,012,989	$2,033,119
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$180,983	$190,508	$200,034
Legal Fees & Permitting	$568,589	$710,736	$888,420
General Facilities			
Roads and Grading	$337,872	$375,414	$412,955
Buildings and Fencing	$125,727	$139,697	$153,666
Engineering & Overhead	$1,932,505	$1,932,505	$1,932,505
Project Contingency	$2,177,267	$2,177,267	$2,177,267
Initial Costs	$294,665	$294,665	$294,665
SUB-TOTAL	$22,194,995	$24,244,599	$25,323,990
TRANSMISSION			
Cost of Upgrade	$1,002,744	$1,055,520	$1,108,296
ANNUAL EXPENSES			
Variable O&M	$14,539	$16,154	$17,770
Fixed O&M	$23,156	$24,375	$25,594
Land Lease	$16,098	$16,945	$17,792
FIRST YEAR O&M	$53,793	$57,474	$61,156

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island	Hawaii	Location:	N. Kohala	Project Code:	(leave blank)

Capacity (MW)	5	Stage (current/future)	Future: Year 2014
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	38,320
Project Life (years)	30	Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	14,094	12,259	11,036
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	13,956	12,136	10,922
CAPITAL COSTS			
Process Capital			
PV Modules	$8,424,000	$9,360,000	$9,828,000
Array Structure & Foundations	$2,063,050	$2,171,632	$2,280,213
Power Condtioning Units	$683,719	$1,051,875	$1,104,469
Electrical & SCADA	$1,488,666	$1,503,703	$1,518,740
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$162,885	$171,458	$180,030
Legal Fees & Permitting	$560,462	$700,577	$875,721
General Facilities			
Roads and Grading	$270,298	$300,331	$330,364
Buildings and Fencing	$118,069	$131,188	$144,306
Engineering & Overhead	$1,525,141	$1,525,141	$1,525,141
Project Contingency	$1,720,807	$1,720,807	$1,720,807
Initial Costs	$232,693	$232,693	$232,693
SUB-TOTAL	$17,527,343	$19,161,566	$20,047,256
TRANSMISSION			
Cost of Upgrade	$361,000	$380,000	$399,000
ANNUAL EXPENSES			
Variable O&M	$15,525	$17,251	$18,976
Fixed O&M	$21,943	$23,098	$24,253
Land Lease	$6,374	$6,709	$7,044
FIRST YEAR O&M	$43,842	$47,058	$50,273

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island	Oahu	Location:	Pearl Harbor	Project Code:	(leave blank)

Capacity (MW)	5	Stage (current/future)	Future: Year 2014
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	38,320
Project Life (years)	30	Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	12,361	10,751	9,679
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	12,240	10,643	9,579
CAPITAL COSTS			
Process Capital			
PV Modules	$8,424,000	$9,360,000	$9,828,000
Array Structure & Foundations	$2,063,050	$2,171,632	$2,280,213
Power Condtioning Units	$683,719	$1,051,875	$1,104,469
Electrical & SCADA	$1,488,666	$1,503,703	$1,518,740
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$162,885	$171,458	$180,030
Legal Fees & Permitting	$560,462	$700,577	$875,721
General Facilities			
Roads and Grading	$270,298	$300,331	$330,364
Buildings and Fencing	$118,069	$131,188	$144,306
Engineering & Overhead	$1,525,141	$1,525,141	$1,525,141
Project Contingency	$1,720,807	$1,720,807	$1,720,807
Initial Costs	$233,075	$233,075	$233,075
SUB-TOTAL	$17,527,725	$19,161,948	$20,047,638
TRANSMISSION			
Cost of Upgrade	$1,002,744	$1,055,520	$1,108,296
ANNUAL EXPENSES			
Variable O&M	$13,616	$15,129	$16,642
Fixed O&M	$21,943	$23,098	$24,253
Land Lease	$12,747	$13,418	$14,089
FIRST YEAR O&M	$48,307	$51,645	$54,984

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island	Hawaii	Location:	N. Kohala	Project Code:	(leave blank)

Capacity (MW)	5	Stage (current/future)	Future: Year 2020
Resource (kWh/m²)	2,358	Extent (PV module area, m²)	36,495
Project Life (years)	30	Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	14,261	12,404	11,167
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	14,122	12,280	11,052
CAPITAL COSTS			
Process Capital			
PV Modules	$6,318,000	$7,020,000	$7,371,000
Array Structure & Foundations	$1,485,396	$1,563,575	$1,641,753
Power Condtioning Units	$512,789	$788,906	$828,352
Electrical & SCADA	$1,050,254	$1,060,863	$1,071,471
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$146,596	$154,312	$162,027
Legal Fees & Permitting	$553,120	$691,400	$864,249
General Facilities			
Roads and Grading	$216,238	$240,265	$264,291
Buildings and Fencing	$114,370	$127,077	$139,785
Engineering & Overhead	$1,157,122	$1,157,122	$1,157,122
Project Contingency	$1,309,568	$1,309,568	$1,309,568
Initial Costs	$177,112	$177,112	$177,112
SUB-TOTAL	$13,318,120	$14,582,362	$15,293,503
TRANSMISSION			
Cost of Upgrade	$361,000	$380,000	$399,000
ANNUAL EXPENSES			
Variable O&M	$14,178	$15,753	$17,328
Fixed O&M	$19,804	$20,846	$21,889
Land Lease	$5,634	$5,931	$6,227
FIRST YEAR O&M	$39,616	$42,530	$45,444

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Photovoltaics (fixed, tilted at 15°)

Island	Oahu	Location:	Pearl Harbor	Project Code:	(leave blank)

Capacity (MW)	5	Stage (current/future)	Future: Year 2020
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	36,495
Project Life (years)	30	Construction Time (years)	1

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	12,507	10,878	9,793
Expected Losses (%)	0.98%	1.00%	1.03%
Net Energy (MWh/yr)	12,385	10,769	9,693
CAPITAL COSTS			
Process Capital			
PV Modules	$6,318,000	$7,020,000	$7,371,000
Array Structure & Foundations	$1,485,396	$1,563,575	$1,641,753
Power Condtioning Units	$512,789	$788,906	$828,352
Electrical & SCADA	$1,050,254	$1,060,863	$1,071,471
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$146,596	$154,312	$162,027
Legal Fees & Permitting	$553,120	$691,400	$864,249
General Facilities			
Roads and Grading	$216,238	$240,265	$264,291
Buildings and Fencing	$114,370	$127,077	$139,785
Engineering & Overhead	$1,157,122	$1,157,122	$1,157,122
Project Contingency	$1,309,568	$1,309,568	$1,309,568
Initial Costs	$177,445	$177,445	$177,445
SUB-TOTAL	$13,318,453	$14,582,695	$15,293,836
TRANSMISSION			
Cost of Upgrade	$1,002,744	$1,055,520	$1,108,296
ANNUAL EXPENSES			
Variable O&M	$12,434	$13,816	$15,197
Fixed O&M	$19,804	$20,846	$21,889
Land Lease	$11,268	$11,861	$12,455
FIRST YEAR O&M	$43,506	$46,523	$49,540

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Hydroelectric

Island	Hawaii	Location:	Umauma Stream	Project Code:	

Capacity (MW)	13.8	Stage (current/future)	future-2014
Resource (cfs, max)	260	Extent (feet of head)	835
Project Life (years)	50	Construction Time (years)	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	42,952	42,093	41,663
Expected Losses (%)	4.50%	4.50%	4.50%
Net Energy (MWh/yr)	$41,019	$40,199	$39,788
CAPITAL COSTS			
Process Capital			
Intake Structure	$269,778	$283,380	$297,549
Penstock	$7,780,012	$8,172,282	$8,580,896
Tailrace	$367,546	$386,077	$405,381
Diversion Structure	$1,957,522	$2,056,220	$2,159,031
Powerhouse	$1,351,800	$1,419,958	$1,490,956
Turbine	$2,503,455	$2,629,680	$2,761,164
Generaator	$3,356,913	$3,526,169	$3,702,477
Switchgear	$702,705	$738,136	$775,042
Equipment Installation	$231,167	$242,822	$254,963
Interconnection	$1,126,439	$1,183,234	$1,242,396
Legal Fees & Permitting	$703,510	$738,982	$775,931
Environmental Monitoring	$480,459	$504,684	$529,918
General Capital Facilities			
Access Road	$694,318	$729,325	$765,792
Station Service	$231,167	$242,822	$254,963
Telecommunications	$61,397	$64,493	$67,718
Engineering Services			
Engineering	$1,745,455	$1,833,461	$1,925,134
Construction Management	$1,745,455	$1,833,461	$1,925,134
Post Construction Environmental	$108,724	$114,206	$119,917
Project Contingency	$2,541,782	$2,669,939	$2,803,436
SUB-TOTAL	$27,959,604	$29,369,332	$30,837,799
TRANSMISSION			
Cost of Upgrade	$1,050,830	$1,103,813	$1,159,004
ANNUAL EXPENSES			
Variable O&M	$91,456	$96,068	$100,871
Fixed O&M	$49,212	$51,693	$54,278
Rep. Spare Parts (sinking fund)	$27,960	$29,370	$30,838
Land Lease	$26,861	$28,216	$29,626
Federal Fees	$11,640	$12,227	$12,838
FIRST YEAR O&M	$207,130	$217,573	$228,452

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Hydroelectric

Island	Kauai	Location:	Wailua River	Project Code:	

Capacity (MW)	13.8	Stage (current/future)	future-2014
Resource (cfs, max)	260	Extent (feet of head)	835
Project Life (years)	50	Construction Time (years)	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	17,200	16,856	16,684
Expected Losses (%)	2.50%	2.50%	2.50%
Net Energy (MWh/yr)	16,770	16,435	16,267
CAPITAL COSTS			
Process Capital			
Intake Structure	$234,589	$246,417	$258,738
Penstock	$3,868,028	$4,063,055	$4,266,207
Tailrace	$114,608	$120,387	$126,406
Diversion Structure	$936,206	$983,410	$1,032,580
Powerhouse	$538,761	$565,925	$594,222
Turbine	$997,754	$1,048,061	$1,100,464
Generaator	$1,496,634	$1,572,095	$1,650,699
Switchgear	$459,835	$483,020	$507,171
Equipment Installation	$116,399	$122,268	$128,381
Interconnection	$355,208	$373,117	$391,773
Legal Fees & Permitting	$180,508	$189,609	$199,090
Environmental Monitoring	$80,584	$84,647	$88,879
General Capital Facilities			
Access Road	$85,956	$90,290	$94,805
Sable Storm Ditch	$107,445	$112,863	$118,506
Relocate USGS Gage	$28,652	$30,097	$31,602
Station Service	$107,445	$112,863	$118,506
Telecommunications	$28,652	$30,097	$31,602
Engineering Services			
Engineering	$779,770	$819,086	$860,040
Construction Management	$779,770	$819,086	$860,040
Post Construction Environmental	$80,584	$84,647	$88,879
Project Contingency	$1,137,739	$1,195,104	$1,254,859
SUB-TOTAL	$12,515,127	$13,146,142	$13,803,449
TRANSMISSION			
Cost of Upgrade	$1,050,830	$1,103,813	$1,159,004
ANNUAL EXPENSES			
Variable O&M	$103,928	$109,168	$114,627
Fixed O&M	$49,816	$52,328	$54,944
Rep. Spare Parts (sinking fund)	$12,527	$13,158	$13,816
Land Lease	$15,989	$16,795	$17,635
Federal Fees	$7,995	$8,398	$8,818
FIRST YEAR O&M	$190,255	$199,848	$209,840

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Hydroelectric

Island	Hawaii	Location:	Umauma Stream	Project Code:	

Capacity (MW)	13.8	Stage (current/future)	future-2020
Resource (cfs, max)	260	Extent (feet of head)	835
Project Life (years)	50	Construction Time (years)	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	42,952	42,093	41,663
Expected Losses (%)	4.50%	4.50%	4.50%
Net Energy (MWh/yr)	$41,019	$40,199	$39,788
CAPITAL COSTS			
Process Capital			
Intake Structure	$269,778	$283,380	$297,549
Penstock	$7,780,012	$8,172,282	$8,580,896
Tailrace	$367,546	$386,077	$405,381
Diversion Structure	$1,957,522	$2,056,220	$2,159,031
Powerhouse	$1,351,800	$1,419,958	$1,490,956
Turbine	$2,503,455	$2,629,680	$2,761,164
Generaator	$3,356,913	$3,526,169	$3,702,477
Switchgear	$702,705	$738,136	$775,042
Equipment Installation	$231,167	$242,822	$254,963
Interconnection	$1,126,439	$1,183,234	$1,242,396
Legal Fees & Permitting	$703,510	$738,982	$775,931
Environmental Monitoring	$480,459	$504,684	$529,918
General Capital Facilities			
Access Road	$694,318	$729,325	$765,792
Station Service	$231,167	$242,822	$254,963
Telecommunications	$61,397	$64,493	$67,718
Engineering Services			
Engineering	$1,745,455	$1,833,461	$1,925,134
Construction Management	$1,745,455	$1,833,461	$1,925,134
Post Construction Environmental	$108,724	$114,206	$119,917
Project Contingency	$2,541,782	$2,669,939	$2,803,436
SUB-TOTAL	$27,959,604	$29,369,332	$30,837,799
TRANSMISSION			
Cost of Upgrade	$1,050,830	$1,103,813	$1,159,004
ANNUAL EXPENSES			
Variable O&M	$91,456	$96,068	$100,871
Fixed O&M	$36,909	$38,770	$40,708
Rep. Spare Parts (sinking fund)	$27,960	$29,370	$30,838
Land Lease	$26,861	$28,216	$29,626
Federal Fees	$11,640	$12,227	$12,838
FIRST YEAR O&M	$194,827	$204,650	$214,882

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Hydroelectric

Island	Kauai	Location:	Wailua River	Project Code:	

Capacity (MW)	13.8	Stage (current/future)	future-2020
Resource (cfs, max)	260	Extent (feet of head)	835
Project Life (years)	50	Construction Time (years)	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	17,200	16,856	16,684
Expected Losses (%)	2.50%	2.50%	2.50%
Net Energy (MWh/yr)	$16,770	$16,435	$16,267
CAPITAL COSTS			
Process Capital			
Intake Structure	$234,589	$246,417	$258,738
Penstock	$3,868,028	$4,063,055	$4,266,207
Tailrace	$114,608	$120,387	$126,406
Diversion Structure	$936,206	$983,410	$1,032,580
Powerhouse	$538,761	$565,925	$594,222
Turbine	$997,754	$1,048,061	$1,100,464
Generaator	$1,496,634	$1,572,095	$1,650,699
Switchgear	$459,835	$483,020	$507,171
Equipment Installation	$116,399	$122,268	$128,381
Interconnection	$355,208	$373,117	$391,773
Legal Fees & Permitting	$180,508	$189,609	$199,090
Environmental Monitoring	$80,584	$84,647	$88,879
General Capital Facilities			
Access Road	$85,956	$90,290	$94,805
Sable Storm Ditch	$107,445	$112,863	$118,506
Relocate USGS Gage	$28,652	$30,097	$31,602
Station Service	$107,445	$112,863	$118,506
Telecommunications	$28,652	$30,097	$31,602
Engineering Services			
Engineering	$779,770	$819,086	$860,040
Construction Management	$779,770	$819,086	$860,040
Post Construction Environmental	$80,584	$84,647	$88,879
Project Contingency	$1,137,739	$1,195,104	$1,254,859
SUB-TOTAL	$12,515,127	$13,146,142	$13,803,449
TRANSMISSION			
Cost of Upgrade	$1,050,830	$1,103,813	$1,159,004
ANNUAL EXPENSES			
Variable O&M	$103,928	$109,168	$114,627
Fixed O&M	$37,362	$39,246	$41,208
Rep. Spare Parts (sinking fund)	$12,527	$13,158	$13,816
Land Lease	$15,989	$16,795	$17,635
Federal Fees	$7,995	$8,398	$8,818
FIRST YEAR O&M	$177,801	$186,766	$196,104

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Geothermal

Island: Hawaii

Location: Kilauea

Ownership: Puna Geothermal Venture

Project Code:

Capacity (Net MW)	30	Stage (current/future):	Future (2014)
Resource	High enthalpy	Extent (# of units):	1
Project Life (years)	30	Construction Time (years):	2
Geology Type	Rift Zone		

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	286,000	280,200	274,600
Expected Losses (%)	9%	10%	11%
Net Energy (MWh/yr)	260,300	252,200	244,400
CAPITAL COSTS ($)			
Process Capital			
Exploration & Assessment	40,000	70,000	100,000
Production & Injection Wells	20,000,000	24,000,000	28,000,000
Gathering/Injection System	1,600,000	2,200,000	2,900,000
Power Plant	36,000,000	42,000,000	48,000,000
Substation Tie-In	1,000,000	1,300,000	1,600,000
Water Supply	40,000	60,000	80,000
Permitting, Legal, Environmental	200,000	400,000	700,000
General Facilities			
Roads & Site Work	500,000	700,000	900,000
Control and Office Buildings	400,000	500,000	600,000
Land Acquisition	50,000	100,000	150,000
Engineering & Overhead	4,000,000	5,000,000	6,000,000
Project Contingency	6,400,000	7,600,000	8,900,000
Initial Costs	1,300,000	1,500,000	1,800,000
TOTAL CAPITAL COSTS ($)	71,530,000	85,430,000	99,730,000
Capital Cost per kW (excluding transmission)	2,384	2,848	3,324
Capital Cost per kW (including transmission)	2,399	2,864	3,343
ANNUAL EXPENSES ($)			
Variable O&M	1,400,000	1,800,000	2,300,000
Fixed O&M	2,800,000	3,700,000	4,500,000
Land Lease	300,000	500,000	700,000
TOTAL FIRST YEAR O&M	4,500,000	6,000,000	7,500,000
O&M per KWh (mills)	17.3	23.8	30.7

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Geothermal

Island: Hawaii | Location: Kilauea | Project Code:

Ownership: Puna Geothermal Venture

Capacity (Net MW)	30	Stage (current/future):	Future (2020)
Resource	High enthalpy	Extent (# of units):	1
Project Life (years)	30	Construction Time (years):	2
Geology Type	Rift Zone		

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	286,000	280,200	274,600
Expected Losses (%)	9%	10%	11%
Net Energy (MWh/yr)	260,300	252,200	244,400
CAPITAL COSTS ($)			
Process Capital			
Exploration & Assessment	40,000	70,000	100,000
Production & Injection Wells	20,000,000	24,000,000	28,000,000
Gathering/Injection System	1,600,000	2,200,000	2,900,000
Power Plant	36,000,000	42,000,000	48,000,000
Substation Tie-In	1,000,000	1,300,000	1,600,000
Water Supply	40,000	60,000	80,000
Permitting, Legal, Environmental	200,000	400,000	700,000
General Facilities			
Roads & Site Work	500,000	700,000	900,000
Control and Office Buildings	400,000	500,000	600,000
Land Acquisition	50,000	100,000	150,000
Engineering & Overhead	4,000,000	5,000,000	6,000,000
Project Contingency	6,400,000	7,600,000	8,900,000
Initial Costs	1,300,000	1,500,000	1,800,000
TOTAL CAPITAL COSTS ($)	71,530,000	85,430,000	99,730,000
Capital Cost per kW (excluding transmission)	2,384	2,848	3,324
Capital Cost per kW (including transmission)	2,399	2,864	3,343
ANNUAL EXPENSES ($)			
Variable O&M	1,400,000	1,800,000	2,300,000
Fixed O&M	2,800,000	3,700,000	4,500,000
Land Lease	300,000	500,000	700,000
TOTAL FIRST YEAR O&M	4,500,000	6,000,000	7,500,000
O&M per KWh (mills)	17.3	23.8	30.7

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Municipal Solid Waste - Electricity

Island: Hawaii Location: East Island

Capacity (MW electricity):	10	Stage (current/future):	future (2014)
Resource (dry tons/year)	69,894	Extent (harvested acres/yr):	N/A
Project Life (years)	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	72,270	65,700	59,130
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	72,270	65,700	59,130
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	7,784,416	9,730,521	11,676,625
Feed handling and prep.	2,918,288	3,647,860	4,377,432
Gasification & compressor/precooler	5,149,257	6,436,571	7,723,886
Physical cleanup	315,491	394,363	473,236
Ash handling	304,223	380,279	456,335
Gas turbine	2,664,000	3,330,000	3,996,000
Balance of Plant	2,297,038	2,871,297	3,445,556
Legal fees & permitting	213,079	266,349	319,618
General Facilities			
Engineering & overhead	1,515,205	1,894,007	2,272,808
Project Contingency	2,316,100	2,895,125	3,474,150
Initial Cost	635,140	793,926	952,711
SUB-TOTAL	26,112,237	32,640,297	39,168,356
TRANSMISSION			
Size (kV)	N/A		
Distance (Miles)			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M ($)	(1,287,910)	(736,217)	(184,525)
Fixed O&M ($)	615,600	769,500	923,400
Land Lease	1,120	1,400	1,680
FIRST YEAR O&M	(671,190)	34,683	740,555

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Municipal Solid Waste - Electricity

Island: Hawaii Location: East Island

Capacity (MW electricity):	10	Stage (current/future):	future (2020)
Resource (dry tons/year)	69,894	Extent (harvested acres/yr):	N/A
Project Life (years)	30	Construction Time (years):	2

ENERGY PRODUCTION	**OPTIMISTIC**	**NOMINAL**	**CONSERVATIVE**
Gross Energy (MWh/yr)	72,270	65,700	59,130
Expected Losses (%)	0	0	0
Net Energy (MWh/yr)	72,270	65,700	59,130
CAPITAL COSTS			
Process Capital			
MSW to RDF front-end processing	7,005,975	8,757,469	10,508,962
Feed handling and prep.	2,626,459	3,283,074	3,939,689
Gasification & compressor/precooler	4,634,331	5,792,914	6,951,497
Physical cleanup	283,942	354,927	425,912
Ash handling	273,801	342,251	410,701
Gas turbine	2,397,600	2,997,000	3,596,400
Balance of Plant	2,067,334	2,584,167	3,101,001
Legal fees & permitting	191,771	239,714	287,657
General Facilities			
Engineering & overhead	1,363,685	1,704,606	2,045,527
Project Contingency	2,084,490	2,605,612	3,126,735
Initial Cost	571,626	714,533	857,440
SUB-TOTAL	23,501,014	29,376,267	35,251,521
TRANSMISSION			
Size (kV)	N/A		
Distance (Miles)			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M ($)	(1,368,800)	(837,330)	(305,860)
Fixed O&M ($)	584,820	731,025	877,230
Land Lease	1,120	1,400	1,680
FIRST YEAR O&M	(782,860)	(104,905)	573,050

APPENDIX B: SMALL-SCALE RENEWABLE ENERGY

Incentives in Hawaii

The State of Hawaii has enacted legislation that helps defray the cost of small-scale renewable energy systems installed by residential or commercial electric customers. One such incentive is net metering, which was enacted in June 2001. Residential and small commercial customers may install solar, wind, biomass, or hydroelectric systems up to 10 kW, and apply for net metering with their utility. Utilities offer net metering on a first-come, first-serve basis up to a maximum of 0.5% of the utility's peak demand. Excess on-site electric production and utility electric consumption are netted each month. For example, if over a month the on-site system produced 100 kWh of excess electricity and consumed 1,000 kWh from the utility, the customer would receive a bill for 900 kWh from the utility.

Another incentive is the commercial and residential solar and wind energy credit. A state income tax credit on the cost of equipment and installation for wind, photovoltaic (PV), and solar thermal systems is available. The credit is 20% for wind systems and 35% for PV and solar thermal systems. The credits are capped as shown in Table B-1.

Table B-1
Limits on State Income Tax Credits

Property Type	Solar	Wind
Single-family residential	$1,750	$1,500
Multi-family residential	$350/unit	$200/unit
Commercial	$250,000	$250,000

Excess credits cannot be carried forward to future year tax obligations. However, this credit can be taken in conjunction with the federal credit of 35%.

For a commercial customer with a tax liability, these incentives, along with accelerated depreciation, could cover up to 80% of the system cost. The remainder is often covered through net metering. On average, a commercial system could see a payback period as low as 5-6 years. Residential systems' payback period is generally longer, more in the range of 15 years. Actual payback period depends on many factors including, but not limited to, utility rates, the actual amount of incentive received, actual production, tax liability, and maintenance costs.

Photovoltaic Systems

Photovoltaic systems have a large residential and commercial market. With few moving parts, customers are not burdened with high operation and maintenance costs nor with the hassle of repair time. PV systems can work in both remote, off-grid operations, and in grid-connected, net metering applications. Commercial building roofs often provide large expanses of flat surface ideal for placement of PV panels. This is particularly useful in areas, such as Hawaii, where land area is at a premium. Building integrated technologies such as PV roofing tiles optimize residential customer's desires for

traditional looking roofs with green, on-site generation. PV systems have also become widely used in the telecommunications, construction, and transportation markets.

Between 1995 and 2000, the Solar Electric Power Association (SEPA) conducted the TEAM-UP program, a partnership between SEPA, DOE, and photovoltaic manufacturers to track system costs of PV equipment and installation, as well as performance. Projects were broken into two size categories, small-scale residential (under 5 kW) and large-scale commercial (70 kW to 400 kW). During the program, 1,162 PV systems were installed in the continental U.S. for a total of 7.2 MW at a cost of $74.5 million (or $10/W). The projects represented several manufacturers, mounting systems, AC versus DC designs, as well as retrofits and new construction.

As the project moved forward, the trend in small-scale systems moved towards smaller, AC systems (<1.5 kW) due in part to greater flexibility and easier installation even though the cost per unit output was higher. Over the study period, the average installation cost for unit sizes under 1.5 kW was $10-$12.5/W while the average install cost for projects between 1.5 kW and 5 kW was $8/W. In 2000, the average AC system cost was $13/W while other systems only averaged $8/W. Module costs ranged from $4-10.5/W. Inverter costs ranged from $0.6-5.6/W[1].

For large-scale systems, the costs ranged from $5.5-12/W, with an average installation cost of $8.4/W. Table B-2 presents the average costs in 1996 and 2000 for large scale systems[2]. The dramatic decrease in installation cost is due, in part, to gaining experience in installing the systems. Those manufacturers that installed more systems lowered their average system price compared to those that only installed a few systems. Table B-3 presents the average estimated cost for Hawaii in 2004 using the 2004 R.S. Means Construction Cost Index to convert from average mainland costs. The total cost of $8.7/W compares well with the total installed costs offered by Hawaiian based PV providers, which range from $7-10/W.

Table B-2
Average Cost of Large-Scale System and Percent Decrease

Component	1996 ($/W)	2000 ($/W)	% Decrease
Module	8.51	4.49	47%
Inverter	0.70	0.39	44%
Installation[1]	1.72	0.43	75%
Total[2]	10.93	7.16	34%

[1] Installation costs include balance of system costs such as wiring, mounting systems, junction boxes, materials, labor, and installation equipment.
[2] Total does not include shipping costs.

[1] SEPA, Solar Electric Power Association (2001). *Residential PV Systems Cost Report: Cost Analysis for TEAM-UP Residential PV Installations*. Washington, D.C.
[2] SEPA (2001). *Large Systems Cost Report 2001 Update: Cost Analysis for 70 kW and Larger TEAM-UP PV Installations*. Washington, D.C.

Table B-3 Average Estimated Large-Scale System Costs for Hawaii, 2004	
Component	**2004 ($/W)**
Module	5.6
Inverter	0.5
Mounting System	0.6
Installation	0.5
Miscellaneous	1.5
Total[1]	8.7
[1] Total does not include shipping costs.	

Most of today's commercial conversion efficiencies of crystalline-silicon average 12%-15% depending on whether the cell is single-crystal or multi-crystal. In the laboratory, efficiencies have reached as high as 25%. Average daily AC power output of a PV system depends on size, season, climate, and specific location. Given these caveats, one provider's website projects that a 600 Wdc system could provide an average daily AC output of 2-3 kWhs. A 4.5 kWdc system could provide an average of 16-25 kWhs/day. A similarly sized system with battery backup would produce a little less, 15-23 kWhs/day on average.

These types of modules are used most often for roof mounted residential or commercial applications, either off-grid or grid-connected. The Sacramento Municipal Utility District (SMUD) has been operating a solar PV buy-down program for several years, obtaining competitive prices through bulk purchase of PV systems on behalf of their residential customers who sign up for the program. They have received bids for installed system costs for under $5/W.

The Mauna Lani Bay Hotel uses a variety of PV technologies, totaling 668 kW. The first installation, in 1998, was a 100 kW system on the hotel roof. A second system of 140 kW covers the golf facility maintenance building, and provides more than half the power needs of the clubhouse, pro shop, and Clubhouse Restaurant. A third installation is a 288 kW tracking PV system that covers 3 acres, and supplies the majority of the resort's daytime water pumping power needs. The resort also purchased solar golf car canopies, which extend the battery life of the cart through reduced consumption while also reducing the recharge time. These projects among other solar projects at the resort were completed by 2002. In 2003, another array was added as well as a solar thermal system to heat the swimming pool. Projects in 2004 include the construction of a pavilion with PV panels on the rooftop. The hotel expects to save approximately $5 million over 25 years.

A study by the University of Hawaii's School of Architecture has developed higher resolution solar mapping technology (patent pending) to identify possible locations for building integrated and rooftop installations. One such area is a warehouse and small business district near the Honolulu International Airport. The study estimates that a third

of the electrical needs of the surrounding neighborhood could be met through PV installations on the warehouse roofs[3].

Small-Scale Wind

Small wind turbines (0.5 kW to 100 kW) serve both remote operation and grid-connected, net-metered applications. Remote operations typically combine small wind turbines with battery storage, PV, micro-hydro, or diesel generators to create a more on-demand energy supply. Home systems are usually located in rural residential areas, and require 1 acre of land. Tower heights vary from 20 m (64 ft) to 35 m (120 ft). Small wind turbines can operate in average winds as low as 5.5 m/s (12.3 mph).

In a Class 3 regime, typical capacity factors range between 15% and 20%. A 10 kW rural residential system produces, on average, 13,000 kWh annually. A 30 kW grid-connected system for rural residential or small business might produce 55,000 kWh to 95,000 kWh annually, depending on the wind speed at hub height. Actual production will depend on the site specific wind resource.

An energy roadmap for small wind systems produced by AWEA in June 2002 lists the average cost of a 5-15 kW residential wind turbine to be $3,500/kW[4]. Current equipment costs range between $2,000/kW to $4,000/kW, depending on the size of the system. Additional customer costs (i.e., electrical, foundation, erection, permitting, and startup) can add at least 10% to the equipment cost, depending on the system, installer, permit fees, and sales tax. The worst case scenario might add 45%-50% to the equipment costs. Operations and maintenance costs are usually very low for these systems since they have few moving parts. The cost of energy (COE) for small wind energy ranges between 6¢ and18¢/kWh.

The AWEA roadmap also lists goals for the 2020 time frame including reducing costs to between $1,200/kW and $1,800/kW, and increasing annual output. Other goals include capturing the urban residential market. Currently, height restrictions of 10.7 m (35 ft) have limited the use of small wind turbines in these areas. To capture this market, future research is focusing on small, grid-connected machines of 1.5 kW to 1.8 kW on 9-m to 10.7-m (30 ft to 35 ft) towers, producing 100-300 kWh/mo, with expected costs of energy around 10¢/kWh.

Wave Energy Conversion Systems

Wave energy conversion systems are a nascent technology, but several configurations exist including oscillating water columns (OWCs), Pelamis (a.k.a., water snake), McCabe wave pump, Archimedes Wave Swing, Nodding Duck, and IPS Buoy. All of those listed, except for the OWCs, float on top of the open water. The movement of the waves drives hydraulic pumps, and hydraulic accumulators store the energy so that the variable wave

[3] Personal Communication. Steve Meder. School of Architecture, University of Hawaii. March 4, 2004.
[4] AWEA (2002). Roadmap: *A 20-year industry plan for small wind turbine technology*. Colorado: National Renewable Energy Laboratory

energy is delivered at a constant flow. Wave energy is converted to grid acceptable power with power conditioning equipment, and delivered via sub-sea cable. OWCs are shoreline devices that use the wave motion to push a column of air that drives a turbine. The equipment and components of these systems are proven offshore and marine technologies.

Capacity ranges vary widely. For example, Ocean Power Technologies (OPT), which utilizes buoy systems, can scale projects from a few hundred kW to hundreds of MW by adding more buoys. Individual buoys currently have a peak capacity of 50 kW. In two years, OPT expects to have 500 kW peak buoys available. Availability is 90% with downtime similar to current naval buoys (i.e., scraping and painting). Since the total project is modular, buoy maintenance can be done individually leaving the remaining buoys available for energy production. The Pelamis is also scaleable, and the first full-scale test launch of a 750 kW unit occurred in March 2004. Current wave energy research focuses on increasing size (i.e., buoys with peak ratings of 500 kW), increasing efficiency, and advances in power conditioning equipment.

A recent report printed in Energy Wise News, summarized wave energy conversion system costs and performance. For projects in the 65 kW to 600 kW range, utilizing various power take-off and conversion systems, the estimated capital cost ranged from $1,300/kW to $6,200/kW. Capacity factors ranged from 30%-50%[5]. Total installed costs (including engineering, design, and contingency) for grid-connected buoy systems are approximately $920/kW while smaller, remote systems are $2,900/kW[6]. A wave energy FAQ listed wave energy's COE at 7.5¢/kWh in the United Kingdom[7]. A proposed grid-connected project in the 250 MW range proposed by OPT is estimated to have a COE in the 3-4¢/kWh range. Smaller, remote systems are expected to have COEs of 7-10¢/kWh. Because there is only limited experience with wave technologies, it should be noted that these cost projections are speculative and not based on proven commercial operations.

The U.S. Navy in Hawaii is currently working with OPT to install a buoy-type system at the Marine Corps Base Hawaii in Kaneohe Bay. The first buoy has a 20 kW (50 kW peak) capacity, and will connect with the base via a sub-sea cable. The buoy will be one mile off-shore in 100 ft of water. Buoy fabrication is complete, and the buoy is currently in the water tied to the pier at Pacific Shipyards. Deployment is scheduled for mid-May 2004. A $13 million grant covers the cost of the study and research and development. OPT has also recently joined with Iberdrola to build a pilot commercial-scale project off the northern coast of Spain. The project will deploy 10 buoys for a total of 1.25 MW. And as mentioned earlier, OPT is also pursuing a 250 MW grid-connected wave energy system. The buoy system needs a water depth of 60-100 ft. The Hawaiian Islands have numerous potential sites meeting this criterion on the north, or windward, side of the islands. In most cases, the 60-100 ft depth can be reached within 1 mile of the shoreline.

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[5] Sanders, Iain et. al. "An opportunity to ride the crest – New Zealand wave energy potential." *Energy Wise News*, January 2004. <http://www.eeca.govt.nz/Content/EW_NEWS/84jan04/waveturbine.htm> March 17, 2004.

[6] Personal communication. Debbie Montagna, Program Manager, OPT. March 25, 2004.

[7] POEMS (Practical Ocean Wave Energy Management Systems, Inc.). *Ocean Wave Technical FAQs*. January 2004. <http://www.poemsinc.org/FAQwave.html> March 17, 2004.

Another project to watch is Ocean Power Delivery's 750 kW Pelamis. Off-shore sea trials in the North Sea lasted between March and April 2004. Cost and performance information was not publicly available.

Microturbines

Another emerging technology is microturbines, which are gas turbines on the size of 25 kW to 500 kW. Applications include hybrid, combined heat and power, and distributed generation, as the turbines are well suited for small commercial and remote locations. One unit is roughly equivalent to the size of a refrigerator. Microturbines can burn a variety of fuels including landfill gas or biogas. Efficiency ranges between 15%-30%.

Costs for hardware, manuals, software, and training range from $700/kW to $1,100/kW. According to NREL, a typical 30-60 kW unit cost averaged $1,000/kW in 2001. The Installation costs can add 30%-50% to those costs. Though O&M cost data are limited, estimates range between 0.5¢/kWh to 1.6¢/kWh[8]. Installation costs averaged $8,200. U.S. DOE Advanced Microturbine Program hopes to bring costs down to $500/kW. If a microturbine is used in a waste-to-energy application, additional costs would include the equipment, installation, and associated costs for converting the biomass into a biogas. A sorting facility may also be required.

In a waste-to-energy application, facilities using microturbines could be located closer to the source of refuse such as remote population clusters on each island. This proximity to the fuel source would reduce the cost of transporting the refuse to a central landfill or collection station. In a combined heat and power application, which some resorts and businesses on Hawaii are investigating, the microturbine may be a more appropriate size than an aeroderivative or simple cycle combustion turbine.

Hybrid

Hybrid systems combine different renewable technologies or renewable and fossil-fuel technologies to provide cleaner, reliable power. Technologies often considered in hybrid systems include wind turbines, photovoltaic arrays, solar concentrating dishes, sterling engines, microturbines, batteries, fuel cells, and diesel or propane generators. Applications include village power, commercial power parks, industrial power quality, integrated building efficiency, off-grid power, distribution grid support, and water resource management.

Using a combination of technologies addresses individual limitations of fuel inflexibility, efficiency, reliability, emissions, and/or economics. For example, the combination of fuel cells and gas turbines/microturbines can attain conversion efficiencies of 60%-80%,

[8] California Distributed Energy Resource Guide: Microturbines. January 18, 2002. <http://www.energy.ca.gov/distgen/equipment/microturbines/microtubines.html> March 24, 2004.

which are higher than the technologies' efficiencies when operating alone. The combination of Sterling engines and solar dishes can replace the use of diesel generators for remote power applications in sunnier climates. Small wind turbines with a backup power supply such as battery, diesel generator, or fuel cell can provide a steady stream of power with fewer emissions than a diesel generator alone. Wind-solar-battery hybrids are also common.

Several demonstration projects exist, and a sampling is listed below:

- Molokai Wind/Diesel Electric Hybrid, 1990 – 1993: The project comprised a 300 kW wind project and a 100 kW diesel engine. Total cost was $1,570/kW and produced 768,756 kWhs in its first year (only 1.2% from diesel). Approximately 60,000 gallons of fuel were saved. The project supplied semi-firm dispatchable power from its start date in February 1992 until late 1993 when the project was struck by lightening. The project helped supply the energy necessary to run water pump systems.
- Salt River Project, Pima-Maricopa Indian Community, started 1999: Solar dish with sterling engine. During periods of low insolation, back up power supplied by natural gas, hydro, and landfill gas.
- NREL demonstration project in Wales, Alaska: The project comprises 130 kW of wind generation and 365 kW of diesel generation. Fuel consumption was reduced by 50%-60%, and the project provides continuous power.
- Dangling Rope Marina, National Park Service, started 1996: The project consists of a 115 kW PV array, a 2.4 MWh battery bank, and 2-250 kVA propane generators. The risk of diesel fuel spills was eliminated, fuel usage and O&M costs decreased, and reliability increased.

An example of a current, operating hybrid project in Hawaii is Parker Ranch. The project uses 175 kW of PV and 50 kW of wind power. The project cost of $8.9/W was driven by the PV portion. Though exact values were not available, the project produces over 90% of the energy needed to operate the pumps that deliver drinking water to livestock in three grazing areas.

Costs and performance will vary widely among the various hybrid configurations. Existing electricity costs, value of green power, availability of resources, and costs of equipment and installation will all factor into the economic feasibility. Table B-4 shows the basic performance and costs for wind-solar hybrid systems according to pricing lists from Oasis Montana, Inc. and Bergey Windpower.

Given the characteristics of Hawaii's electrical grids, which makes them more susceptible to fluctuations in power from as-available resources, hybrid systems could meet the needs of dispersed population clusters as well as provide more firm levels of power to the grid.

Table B-4
Wind-Solar Pricing

Item	Oasis Montana System 5	Oasis Montana System 7	Bergey Wind-Solar Hybrid – 10.1 kW System	Bergey Wind-Solar Hybrid – 1.2 kW System
Wind Turbine	1 – 1 kW Bergey XL.1 with 64 ft tower ~160 W/h or 3.9 kWh/day @ 10-12 mph average wind speed	1 – 1 kW Bergey XL.1 with 64 ft tower ~160 W/h or 3.9 kWh/day @ 10-12 mph average wind speed	1 – 7.5 kW BWC Excel-R/48 with 100 ft tower.	1 – 1 kW XL.1 with 64 ft tower.
Solar Module	2.8 kW: 28 – Siemens 100 W modules, single-crystalline, frame mounts, etc. ~2,100 Wh/hour of full sun	5.76 kW: 48 – Kyocera 120 W modules, multi-crystalline, frame mounts, etc. ~4,300 Wh/hour of full sun	2.64 kW: 48 – 55 W modules Complete system provides 750 – 1,800 kWh/mo depending on wind and solar resources.	2 – Photowatt 24 VDC, 90 W modules Complete system provides 80 - 200 kWh/mo depending on wind and solar resources.
Battery	24 – 2 V cells, ~2.5 days of storage	36 – 2 V cells, ~2.5 days of storage	84 kWh, 5-string, Battery Bank (5 x B350-8) ~ 1-2 days of storage.	8 – 6 V cells, ~ 2-3 days of storage.
Inverter	4,000 W continuous AC	4,000 W continuous AC	11 kW	1,500 W
Equipment Cost	$33,864	$58,978	$64,100	$6,380
Additional Costs[1]	Not supplied	Not supplied	$6,000 - $25,000	$1,000 - $4,000
Estimated Total Cost[2]	$38,864 - $53,864	$64,978 - $83,978	$70,100 - $89,100	$7,380 - $10,380

[1]Additional costs include shipping, sales tax, permit costs, foundation and anchoring, wire run, turbine and tower erection, PV array assembly, battery racks or vault, electrical hook-up, and inspection fees. They can vary depending on customer or dealer installation, sales tax, diesel generator, etc.
2 For Oasis, assumed $5,000 to $20,000 for System 5 and $6,000 to $25,000 for System 7.