ANALYSIS OF RENEWABLE PORTFOLIO STANDARD OPTIONS FOR HAWAII

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Department of Business, Economic Development & Tourism
by

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ANALYSIS OF RENEWABLE PORTFOLIO STANDARD OPTIONS FOR THE STATE OF HAWAII

EXECUTIVE SUMMARY

During the 2000 Legislative Session, the Hawaii Legislature considered a Renewable Portfolio Standard (RPS) for the State of Hawaii (HB 1883). A RPS is designed to increase the use of renewable energy for electricity production by requiring that a specified percentage of the electricity for the State be generated from renewable sources such as wind, solar, geothermal, hydropower, or biomass.

Following the 2000 Hawaii Legislative session, additional study of a RPS for Hawaii appeared warranted and the Department of Business, Economic Development & Tourism contracted with GDS Associates, Inc., to conduct this analysis. The principal output of this project was an analysis of renewable portfolio standard options using a computer-based spreadsheet model to compare the costs of various RPS options to each other and to the utilities' most recent Integrated Resource Plans (IRPs) which rely almost exclusively on additional fossil-fueled generation. The principal finding was that increased use of renewable energy can result in net savings in electricity costs for the citizens of Hawaii.

Hawaii's Electricity System and Renewable Energy

The use of electricity in Hawaii grew faster between 1990 and 1999 than any other form of energy use. Electricity will play a vital role as Hawaii continues to increase the high technology components of its economy. However, the cost of electricity in Hawaii is the highest of any state in the United States with average revenues per kWh in September 2000 of $0.144 -- over twice U.S. average revenues per kWh of $0.0691.[1]

Hawaii is highly dependent on the use of fossil fuels to generate electricity and without action to increase the use of renewable energy sources, the dependence on fossil fuels is projected to increase. While renewable energy produced 7.6% of electricity sold by Hawaii's utilities statewide in 1999, closures of sugar mills on Kauai and Maui in 2000 will likely reduce the renewable energy contribution to 6.7% in 2001. If no renewable energy is added, only 5.8% of electricity in 2010 will come from renewable sources.

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

- Reduced cost of fuel for electricity generation;
- Reduced reliance on imported oil supplies and exposure to the volatile

[1] Energy Information Administration. *Electric Power Monthly*. December 2000.

prices of the world oil market;

- Risk management by diversifying the portfolio of electricity generation options;
- Job creation and economic benefits; and
- Environmental benefits.

Analysis of Renewable Portfolio Standard Options for Hawaii

GDS developed a computer spreadsheet-based cost model to evaluate potential renewable energy portfolio standards that would set percentages of renewable energy for Hawaii's utilities to meet on a statewide basis by the year 2010. The model calculates annual costs of producing electricity to meet each utility's annual requirements for a period of twenty years. The annual production costs were calculated for a base case comprised of existing units and unit additions included in each utility's current Integrated Resource Plan (IRP), and for four renewable portfolio scenarios.

Since oil prices are a key variable in the model, two oil price estimates are used. The reference case world oil price is $25 per barrel in 2003. The reference case value is intended to represent the mid-point of the OPEC-announced target price “basket” of $22-28 per barrel. A low oil price scenario based on a world oil price of $22 per barrel in 2003 to represent the low range of the OPEC basket was also run. Oil prices were escalated based upon the Gas Research Institute’s (GRI) 2000 Baseline Projection of oil price growth for the Pacific 2 energy demand region comprised of California and Hawaii.

The four RPS scenarios are:

1. 9.5% renewable energy by 2010 under a reference oil price forecast;
2. 10.5% renewable energy by 2010 under a reference oil price forecast;
3. 9.5% renewable energy by 2010 under a low oil price forecast; and
4. 10.5% renewable energy by 2010 under a low oil price forecast.

Each renewable energy portfolio scenario analyzed produced a lower statewide Net Present Value (NPV) of annual revenue requirements for generation than the base case of the utilities’ IRPs. These results show that installation of renewable energy resources could reduce the cost of electricity to customers during the 2001 through 2010 period by a NPV of about $27.8 million for the 9.5% RPS/low price oil case to $43.1 million for the 10.5% RPS/reference oil price case. Table ES-1 summarizes the four scenarios and the savings they provide during the 2001-2010 period and for the 2001-2020 period.

Table ES-1. Net Present Value of Estimated Savings Under Renewable Portfolio Standards

RPS	Savings 2001-2010	Savings 2001-2020
9.5% RPS/Reference Oil Price Case	$ 38,960,000	$ 86,195,000
10.5% RPS/Reference Oil Price Case	$ 43,065,000	$ 98,385,000
9.5% RPS/Low Oil Price Case	$ 27,809,000	$ 62,410,000
10.5% RPS/Low Oil Price Case	$ 30,115,000	$ 72,098,000

These savings are positive, but relatively small in comparison to the estimated total reference case base cost of generation over this period ($3.172 billion). As explained in Section III.C, the $3.172 billion represents only the costs that would change in the RPS cases, not the actual total generation costs. Savings vary from an estimated statewide average in 2010 of 7/100 of a cent per kWh for the 9.5% RPS/low price oil case and 40/100 of a cent per kWh for the 10.5% RPS/reference oil price case. This equates to a statewide annual average savings of about $5.10 to $29.20 per residential customer in 2010, based on an average 7300 kWh annual electricity use. Additional savings would be realized if oil prices escalated above the levels modeled. Tables III-10 and III-11 in the main report depict savings by utility service area.

These savings result from using new renewable resources to generate electricity instead of existing and planned high cost fossil units. While the geothermal resources modeled in the scenarios provide firm power and can substitute for fossil fuel generation, the wind resources are intermittent resources. Obviously, when the wind does not blow, wind generators cannot produce power. Thus they cannot be counted on to meet peak demands which generally fall in the early evening. However, when wind is available, it can allow fossil fuel units to cut back on production, reducing fossil fuel use. Production cost savings, while small when compared to total utility costs, are large enough to offset incremental capital costs incurred by building the new renewable energy projects. In addition to the cost savings, the additional benefits of increased renewable energy use cited above would be realized.

The results of the GDS Renewable Portfolio Analysis model described indicate that a RPS can be established in Hawaii for 2010 at lower cost than the planned utility systems. Recognition of the benefits described above led several other states to adopt a RPS to ensure that desired levels of renewable energy are attained. Appendix 2 of this report presents examples of specific benefits of renewable resources found to exist by those states that have implemented Renewables Portfolio Standards.

Recommendations for RPS Implementation

Section IV offers a number of recommendations for RPS implementation in Hawaii, which are briefly summarized below.

The potential role of the Legislature in mandating RPS. Implementation of a RPS requires the support of the State Legislature and the Public Utilities Commission

(PUC). Without serious state commitment to clean electricity, the market share of renewable energy will stagnate or decline as has occurred in Hawaii in the 1990s. As in most states, legislation will be needed to enact a RPS in Hawaii. Experience in other states has shown that broad legislative support has been necessary in order to implement a RPS. While the PUC could enact a RPS through regulations, our research indicates that the broader support of the legislature has been necessary in most RPS states to have successful implementation and acceptance by key market actors.

The role of the Public Utilities Commission in implementing a RPS. The PUC will play an important role in implementation. The success of a RPS is highly dependent on the rules of implementation and on enforcement by the Public Utilities Commission (PUC). This will be especially true in Hawaii, given the separate electric grids on the individual islands and likelihood that some islands will have more opportunity to provide increases in renewable energy than other islands.

General considerations in implementing a RPS. Several important lessons learned in the development and implementation of a RPS have been identified in the literature and in the interviews with persons involved in RPS implementation in other states and should be considered in development of a RPS for Hawaii. These lessons, described in detail in Section IV of this report, are:

- **Establish realistic goals**. Development of a RPS requires making informed tradeoffs between different program designs. Efforts should be focused on technologies or markets where state policies might have a lasting impact. The GDS analysis was based upon the latest identification and characterization of potential renewable resources in Hawaii and the costs of these resources were updated. The analysis summarized above shows that the recommended goals of 9.5% and 10.0% are realistic.
- **Strive for market transformation.** Successful policies will strive to "transform" markets and create a continuing demand for renewables after the policy is removed. A successful RPS will demonstrate the benefits of renewable energy and will contribute to further reduction in costs and technological improvements.
- **Identify eligible projects and technology.** GDS recommended that technologies for Hawaii include wind, hydroelectricity, geothermal, solar photovoltaic and solar thermal, and biomass. Biomass would include agricultural and forest product wastes, landfill gas, waste-to-energy, and other organic wastes. Ocean thermal energy conversion (OTEC) and wave power would also qualify as renewable energy sources.
- **Enhance resource diversity by including a mix of technologies.** Renewable energy should include a mix of technologies with diverse characteristics, market needs, costs, and social benefits.
- **Establish policy stability through reasonable duration.** Short duration policies can create immediate markets for renewables but can be destabilizing, making the renewable industry vulnerable to changing

political forces. Policy duration and stability are especially important for RPS where facilities will be brought on-line under the expectation of continued support. Without some certainty in the length and stability of the policy, new renewable generators will need to amortize their capital costs over a shortened period, increasing the near-term cost. Hawaii's RPS should cover a period of ten years and should be evaluated every five years for a new ten year period. This will allow updating and revision of goals based on new cost and performance information.

- **Structure purchase contracts so that payments for renewable energy are not tied to fossil fuel prices.** Previously in Hawaii, most renewable energy power purchase agreements were tied to utility costs that are significantly influenced by the cost of fossil fuel. To allow renewable energy to provide cost savings in the face of expected oil prices, it will be important to develop innovative contract terms for renewable energy projects that provide a fair rate of return to renewable energy project developers without linking payments to future cost trends for fossil fuels. Since most renewable energy projects have little or no on-going fuel costs, it can be argued that contract payments need not emphasize possible escalation in fuel prices. This could be accomplished in one of the following ways: (a) specifying cost caps for renewable energy; (b) setting a maximum allowable rate of return for renewable energy projects; or (c) prohibiting tying contracts for renewable energy to fossil fuel prices.

In addition, Section IV provides the following: an outline of a recommended request for proposals and Standard Offer Contract structured to break the link between the cost of renewable energy and fossil fuel prices; recommendations for a cost cap for renewable resources; recommendations regarding penalties for not meeting the RPS, and offers options for trading of renewable energy resource credits to allow a RPS to be met by utilities not able to build sufficient renewable energy facilities in their own service territory.

Standardized RFP and Standard Offer Contract. By using a standardized request for proposals (RFP) and a standard offer contract, the acquisition of renewable energy can be greatly simplified and the expense to both the utility and renewable energy developer can be reduced. In addition, such a contract can be designed to break the link with volatile fossil fuel costs by use of appropriate pricing language. Recommended language is provided in the main report.

Cost Caps. Cost caps can be an effective mechanism to ensure that Hawaii ratepayers do not pay too much for renewable energy. None of the states with a RPS have enacted explicit cost caps. According to National Renewable Energy Laboratory staff, lessons from other states indicate that if a cost cap is desired for specific renewable energy technologies, it should be set just above the expected market price of renewable energy credits. A cap that is set too low can result in a shortage of renewable energy generation relative to the target, can increase administrative costs, and can reduce market efficiencies. GDS recommends against an explicit cost cap, and supports an approach that focuses on a standardized request for proposals and a standard offer contract for the acquisition of cost-effective renewable energy resources.

Possible Penalties for Not Meeting the RPS. Many states have penalties that are assessed on utilities that do not meet their RPS. HB 1883 proposed the following language, "Failure to produce and receive approval of the required number of renewable energy credits shall result in a penalty which shall be equal to three times the market value of a renewable energy credit for each credit that is not produced." If a credit trading system, discussed in the following section is not adopted, another form of penalty may be required. These could include a fine of several times the revenue requirements of a kWh of electricity sold by the utility multiplied by the shortfall in kWh. Some states leave sanctions to the discretion of their PUC. Some make meeting the RPS a requirement to maintain the utility's license.

Credit Trading to Meet the RPS. The study provided by GEC lists each Hawaii utility's options to add renewable energy to its system. For various reasons, one or more of Hawaii's utilities may not be able to achieve an RPS by 2010, or it may not be able to meet an established intermediate milestone. Other utilities, certainly HELCO, will be able to exceed the proposed RPS. To accommodate these differences, GDS recommends that the State of Hawaii consider a renewable energy credit trading mechanism or requiring each company (the HECO companies together and KE separately) to meet the RPS on a company basis.

If there is a system of credit trading for renewable energy, it will be possible to establish a maximum credit price for renewable energy. That price represents the market price of renewables. If retail suppliers on any of the four utility systems have trouble procuring enough renewable energy credits to meet the RPS; they can buy proxy credits at the pre-established price from the credit administrator. GDS recommends that the PUC serve as the administrator of the credit trading system. The administrator, in turn, takes the proxy credit sale proceeds and goes into the market to buy as many credits as possible until the proceeds are exhausted.

As an alternative to a credit trading arrangement, Hawaii's utility companies could be required to meet the RPS on a by-company rather than by-utility basis. In this case, HECO, HELCO, and MECO would jointly meet the RPS and KE would separately meet the RPS. This appears feasible at least through 2010 and would simplify the process.

I. INTRODUCTION

During the 2000 Legislative Session, the Legislature of the State of Hawaii considered enacting a Renewable Portfolio Standard (RPS) for the State of Hawaii (HB 1883). A RPS is designed to require that a specified percentage of the electricity sold by electric utilities be generated from renewable sources such as wind, solar, geothermal, hydropower, or biomass. Biomass would include agricultural and forest product wastes, landfill gas, waste-to-energy, and other organic wastes. Ocean thermal energy conversion (OTEC) and wave power would also qualify as renewable energy sources. Typically, when a RPS is established, electric utilities are given several years to develop the renewable resources required to meet the RPS goals.

As stated in the final draft of HB 1883, the drafters recognized "the economic, environmental, and fuel diversity benefits of renewable energy resources and to establish a market for renewable energy in Hawaii using the State's significant renewable energy resources and to drive down the cost of renewable energy to consumers. The legislature finds that the benefits of electricity from renewable energy resources accrue to the public at large, thus consumers and electric utilities share an obligation to develop a minimum level of these resources in the State's electric supply portfolio." [2]

The bill indicated that "one way to achieve this objective is through the implementation of "renewables portfolio standards" -- a flexible, market-driven policy that seeks to ensure that the public benefits of wind, solar, biomass, geothermal energy, and other renewable energies continue to be recognized as electricity markets become more competitive. The policy ensures that a minimum amount of renewable energy is included in the portfolio of electricity resources serving the State. By increasing the required amount over time, the standard seeks to increase the sustainability of the electricity industry. Because it is a market standard, renewables portfolio standards rely almost entirely on the private market for its implementation. Market implementation will result in competition, efficiency, and innovation that seeks to deliver renewable energy at the lowest possible cost."[3]

Following the 2000 Hawaii Legislative Session, it appeared that additional study of the potential for a RPS for Hawaii was warranted to deal with concerns expressed about the cost of a RPS. Accordingly, the Department of Business, Economic Development & Tourism (DBEDT) contracted with GDS Associates, Inc., a nationally known energy consulting firm, to conduct further analysis.

The analysis was based upon the identification and characterization of potential renewable resources in Hawaii. Global Energy Concepts, Inc. (GEC), a subcontractor to GDS, updated its earlier study, "Renewable Energy Resource Assessment and Development Program," completed as part of DBEDT's *Hawaii Energy Strategy* program in 1995. In the 1995 study, GEC identified more than 200 potential renewable energy

[2] HB1883 HD2 SD3 (http://www.capitol.hawaii.gov/session2000/bills/hb1883_sd3_.htm)
[3] HB1883 HD2 SD3

projects. For this study, GEC selected those projects that offered the most opportunity to provide cost effective renewable energy in Hawaii. Current cost and performance data were updated for each of these projects. GEC's report, *Update of Selected Cost and Performance Estimates*, is provided as Appendix 1 to this report.

The principal output of this project is an analysis of renewable portfolio standard options using a computer-based spreadsheet to model the costs of various renewable portfolios in comparison to each other and to the utilities' most recent Integrated Resource Plans (IRPs), which rely almost exclusively on additional fossil-fueled generation. Several additional analyses were conducted and their results are included in this report and its appendices.

This study was prepared to support the Director of the Department of Business, Economic Development & Tourism (DBEDT) in his role under Chapter 196, Hawaii Revised Statutes (HRS), as the State's Energy Resources Coordinator (ERC). Chapter 196 assigned the ERC the following duties related to Hawaii's electricity system and the use of renewable energy systems:

(1) Formulate plans . . . and programs . . . for the optimum development of Hawaii's energy resources;

(2) Conduct systematic analysis of existing and proposed energy resource programs . . . which represent the most effective allocation of resources for the development of energy sources;

(3) Formulate and recommend specific proposals, as necessary, for conserving energy and fuel . . .; [and]

(8) Serve as consultant to the governor, public agencies and private industry on matters related to the acquisition, utilization and conservation of energy resources. [4]

In accordance with Chapter 226-18, HRS, the State's energy planning efforts are: "directed toward the achievement of the following objectives, giving due consideration to all:

(1) Dependable, efficient, and economical statewide energy systems capable of supporting the needs of the people;

(2) Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased;

(3) Greater energy security in the face of threats to Hawaii's energy supplies and systems; and

(4) Reduction, avoidance, or sequestration of greenhouse gas emissions from energy supply and use." [5]

[4] Chapter 196, Hawaii Revised Statutes
[5] Chapter 226-18a, Hawaii Revised Statutes

To achieve these objectives, it is the policy of the State of Hawaii to "ensure the provision of adequate, reasonably priced, and dependable energy services to accommodate demand" [6] and to:

(1) Support research and development as well as promote the use of renewable energy sources;

(2) Ensure that the combination of energy supplies and energy-saving systems is sufficient to support the demands of growth;

(3) Base decisions of least-cost supply-side and demand-side energy resource options on a comparison of their total costs and benefits when a least-cost is determined by a reasonably comprehensive, quantitative, and qualitative accounting of their long-term, direct and indirect economic, environmental, social, cultural, and public health costs and benefits; . . .

(5) Ensure to the extent that new supply-side resources are needed, the development or expansion of energy systems utilizes the least-cost energy supply option and maximizes efficient technologies; . . . [and]

(8) Support actions that reduce, avoid, or sequester greenhouse gases in utility, transportation, and industrial sector applications . . . . [7]

The following study indicates that a RPS could help Hawaii comport with its statutory energy objectives and policies.

II. HAWAII'S ELECTRICITY SYSTEM AND RENEWABLE ENERGY

A. The Growing Importance of Electricity to Hawaii

Electricity is vital to modern life. Virtually all of Hawaii's citizens use electricity for essential functions such as lighting, water heating, refrigeration, air conditioning, ventilation, and cooling. At higher elevations, some Hawaii citizens even need heating. Electricity is used to operate home appliances, office machines, industrial equipment, communications systems, and other devices. A small number of electric vehicles charge their batteries with utility electricity.

B. The High Cost of Hawaii's Electricity

Hawaii's electricity use grew faster between 1990 and 1999 than any other form of energy use. Increases in the sales of electricity outpaced growth in Hawaii's de facto population (about 5.5%) and gross state product (GSP) (4.7%) during the period. By 1999, electricity sales were 12.4% greater than in 1990.[8] Electricity sales per capita (de

[6] Chapter 226-18b, Hawaii Revised Statutes
[7] Chapter 226-18c, Hawaii Revised Statutes
[8] DBEDT Energy, Resources, and Technology Division (ERTD) analysis of utility reports to the Public

facto population) grew about 6.6%, and there was a 7.5% growth in electricity sales per real dollar of GSP. As Hawaii continues to increase the high technology components of its economy, its electricity system will play a vital and growing role.

However, the electricity needed by Hawaii's businesses, citizens, and visitors comes at a premium cost. Hawaii's average statewide electricity revenues per kWh were the highest in the nation as of October 2000. The average revenue per kWh in the United States was $0.0679. In Hawaii, average revenues per kWh were $0.144 -- over twice the U.S. average.[9]

Not only were Hawaii's electricity revenues per kWh the highest in the nation in October 2000, electricity revenues per kWh for Hawaii utilities grew much faster than the U.S. average over the years since 1990. Hawaii's revenues per kWh were 59.6% higher than the average for 1990 while the U.S. average was only 3.3% higher. For comparison, Honolulu consumer prices increased about 25.5% from 1990 to 1999 (later data not available).[10]

C. Hawaii's Dependence on Fossil Fuels Is Projected to Increase

Hawaii's dependence on fossil fuels is expected to grow over the coming decade unless action is taken to increase the use of renewable energy. In 1999, Hawaii's four electric utilities sold 9,373.8 Gigawatt hours (GWh) of electricity. Statewide, utility IRPs forecast that electricity sales will grow at an average annual rate of 1.6% during the 1999 through 2010 period, reaching approximately 11,192 GWh in 2010. The individual utility sales for 1999 and 2010, the average annual growth rates for the 1999-2010, and the total projected growth for the period 1999 through 2010 based upon utility forecasts are shown below in Table II-1.

Table II-1. Projected Hawaii Electric Utility Sales Growth, 1999-2010

Utility	1999 Sales (GWh)	Estimated 2010 Sales (GWh)	Projected Annual Growth Rate 1999-2010	Total Projected Growth 1999-2010
HECO	6,992	8,076	1.3%	15.5%
HELCO	922	1,081	1.5%	17.2%
KE	395	622	4.2%	57.6%
MECO	1,065	1,413	2.6%	32.7%
Statewide	9,374	11,192	1.6%	19.4%

In 1999, renewable energy was used to produce 7.2% of the electricity generated for sale by the four electric utilities (This includes utility net generation and amounts sold by IPPs to utilities, before transmission and other losses). Renewable energy generation

Utilities Commission and data compiled by the DBEDT Research and Analysis Division in the on-line version of the *State of Hawaii Data Book 1999* (http://www.hawaii.gov/dbedt/db99/index.html)
[9] Energy Information Administration, *Electric Power Monthly*, February 2001.
[10] DBEDT Research and Analysis Division, *State of Hawaii Data Book1999* on-line (http://www.hawaii.gov/dbedt/db99/index.html)

capacity was reduced in 2000 by the closure of Lihue Plantation on Kauai and Pioneer and Paia Mills on Maui. If the remaining renewable energy resources in operation at the end of 2000 continue in operation through 2010, they will provide an estimated 642 GWh of sales during each year of the period. This will amount to approximately 6.6% of total electricity sales in 2001. As electricity demand grows, the percentage of electricity sales from renewable resources will decline to approximately 5.7% statewide by 2010. Table II-2 shows the generation in Hawaii used to produce electricity for sale to utility customers in Hawaii as of the end of 2000.

Table II-2. Electricity Generation for Utility Sales (End of 2000)

HECO	HELCO	KE	MECO
HECO 1161.0 MW OFS 102.0 MW CT **IPP (Fossil Fuel)** 180.0 MW AFBC 180.0 MW LSFO DTCC 27.0 MW CT **IPP (Renewable)** 46.0 MW MSW 3.2 MW LF Gas	**HELCO** 65.0 MW OFS 45.3 MW CT 42.0 MW IC Diesel 3.4 MW Hydro 1.8 MW Wind **IPP (Fossil Fuel)** 22.0 MW Coal Steam 62.0 MW DTCC **IPP (Renewable)** 30.0 MW Geothermal 12.3 MW Hydro 7.3 MW Wind	**KE** 10.0 MW OFS 42.9 MW CT 44.0 MW IC Diesel **IPP (Renewable)** 8.7 MW Hydro* 4.0 MW Bagasse*	**MECO** 32.4 MW OFS 102.4 MW CT/DTCC 114.9 MW IC Diesel **IPP (Renewable)** 12.0 MW Bagasse/ Oil/Coal Steam** 5.9 MW Hydro*

Abbreviations: OFS - oil-fired steam; CT - combustion turbine; AFBC - atmospheric fluidized bed coal;
LSFO - low sulfur fuel oil; DTCC - dual-train combined cycle; MSW - municipal solid waste;
LF Gas - Landfill Methane Gas; IC Diesel - internal combustion diesel
* Units also provide electricity for own use. ** Contracted firm capacity to MECO

Unless renewable energy resources are increased, by 2010 the percent of electricity sold from renewable resources will amount to only about 3.6% for HECO; 24.1% for HELCO; 5.6% for KE, and 3.7% for MECO. Table II-3 shows renewable energy sales as a percentage of total sales for each utility in 1999 and the estimated percentages for 2001 and 2010.

Table II-3. Estimated Percentages of Utility Electricity Sales from Existing Renewable Energy Resources

Utility	1999	2001	2010
HECO	4.4%	4.1%	3.6%
HELCO	26.1%	28.3%	24.1%
KE	13.9%	7.5%	5.6%
MECO	4.7%	4.7%	3.7%
Statewide	7.2%	6.6%	5.7%

D. Why Hawaii Should Increase the Use of Renewable Energy for Electricity

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

There are substantial benefits to the citizens of Hawaii from increased use of renewable energy resources. The renewable resource benefits listed below are those cited most frequently in the literature.

- 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 sections below discuss these categories of renewable energy benefits in more detail.

1. Reduced Cost of Fuel for Electricity Generation

Electricity generated from oil is the most expensive of all forms of electricity from fossil fuel. As a result, where coal and natural gas are readily available, only 3.4% of electricity is produced from oil. While Mainland utilities may claim that some renewable resources are more expensive, they are comparing those resources to lower electricity generation and fossil fuel costs on the Mainland, which resulted in average revenues per kWh in August 2000 of $0.0713 compared to Hawaii's average of $0.141.

Hawaii not only uses oil for the greatest percentage of its electricity generation (about 75%), but it also pays the highest costs. In July 2000, for example, Hawaii utilities paid $33.47 per barrel of heavy fuel oil -- 21% more than the $27.56 paid on average by U.S. utilities. Oil prices rose dramatically in August through October, but data is not yet available for those months. In 1999, Hawaii utilities paid $234.7 million for oil. In just the first eight months of 2000, they paid over $276 million for oil.[11] Under the Energy Cost Adjustment Clause, the full cost of the fossil fuels used by Hawaii's electric utilities is passed directly to utility customers. Thus, Hawaii's electricity users bear the full risk of volatile fuel prices.

Most renewable energy sources have little or no fuel cost. These include wind, hydro, solar, geothermal, OTEC, and wave. There may be costs associated with some

[11] Energy Information Administration. *Electric Power Monthly*, December 2000 and HECO and MECO *FERC Form 1* and HELCO and KE *Annual Reports* for 1999.

types of biomass, but these costs are at least more predictable and controllable.

2. Reduced Reliance on Imported Oil Supplies and Exposure to the Volatile Prices of the World Oil Market

Our nation's energy security continues to be threatened by our dependency on imported fossil fuels. The United States is now importing more foreign barrels of oil than it ever has. These conventional fossil fuel sources are vulnerable to political instabilities, trade disputes, embargoes, and other disruptions. Oil prices are also extremely volatile. U.S. domestic oil production has been declining since 1970. In 1973, the United States only imported about 34% of its oil. Today, our country imports more than 56% of its petroleum needs, and it is estimated that this could increase to 70% by 2020.[12]

World crude oil prices fell sharply through most of 1997 and 1998, reaching a recent low of $12.02 a barrel (1999 dollars). This was due in part to economic developments in East Asia and the resulting oversupply of oil. Beginning in 1999, actions by the Organization of Petroleum Exporting Countries (OPEC) and some non-OPEC countries to restrain oil production have increased world oil prices. The U.S. Energy Information Administration reference case projects that the average world oil price will increase from $17.35 per barrel in 1999 to about $27.60 per barrel in 2000, falling to about $20.50 per barrel by 2003. In 2020, the projected price reaches $22.41 per barrel.[13] It should also be noted, however, that OPEC has announced its intention to keep oil prices within a range of $22 to $28 a barrel with a $25 per barrel target. OPEC now provides about 40% of U.S. oil imports and is projected to provide 49% by 2020.[14]

Most of the world's oil reserves are now in the Middle East. We have witnessed this shift in economic influence through the last three sharp increases in the world's oil prices: the Arab Oil Embargo in 1974, the Iranian Revolution in 1979, and the Persian Gulf War in 1990. Each crisis resulted in periods of negative economic growth and contributed further to a rising trade deficit.[15]

3. Risk Management by Diversifying the Portfolio of Electricity Generation Options

By broadening the mix of Hawaii's electricity sources, renewables can make the State of Hawaii less vulnerable to volatile fuel prices and interruptions to the fuel supply. Renewable resources, such as wind and solar that do not depend on fossil fuels, are not subject to price fluctuations, such as the huge leaps and falls in oil prices seen over the past thirty years. And since renewable energy is locally produced, it is not vulnerable to

[12] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2000, With Projections to 2020*, December 1999, Table 1 on page 7.
[13] U.S. Department of Energy, Energy Information Administration, *Early Release of the Annual Energy Outlook 2001, With Projections to 2020*, November 2000, http://www.eia.doe.gov/oiaf/aeo/earlyrelease /index.html.
[14] Ibid.
[15] National Renewable Energy Laboratory web site. *Energy Security*. (http://www.nrel.gov).

supply interruptions from outside the state or country.[16]

4. Job Creation and Economic Benefits

Hawaii must import oil and coal to provide electricity and fuel. The cost of these fossil fuels (not including transportation fuels) for 2000 is estimated by DBEDT at $1.7 billion, or 4.5% of estimated Gross State Product. Every dollar spent on energy imports is a dollar that the local economy loses. Renewable energy resources, however, are developed locally and there is no need to import fuels from foreign countries. Once the renewable energy generator has been purchased, more of the dollars spent on renewable energy stay at home, creating more jobs and fostering economic growth.[17]

Renewable energy technologies are more labor intensive than fossil fueled technologies. Jobs evolve directly from the manufacture, design, installation, servicing, and marketing of renewable energy products. Most of the local jobs would come from the installation, operation and maintenance, and marketing of the renewable systems. Jobs even arise indirectly from businesses that supply renewable energy companies with raw materials, transportation, equipment, and professional services, such as accounting and clerical services. In turn, the wages and salaries generated from these jobs provide additional income in the local economy. Renewable energy companies also contribute more tax revenue locally than conventional energy sources.[18]

A study done for the State of Wisconsin found that displacement of fossil fuel energy by local renewable energy would prevent the loss of $6 billion from the state to pay for extraction, refinement, and transportation of fossil fuels. By accelerating economic growth (by keeping the $6 billion in state), renewables located in the state could provide between 48,202 and 63,234 new job-years.[19] Renewable energy firms can also form a formidable economic sector that contributes significantly to a locality's economic well being. The State of Washington's Department of Trade and Economic Development, for example, identified 134 renewable energy firms in that state. The companies had 900 employees and annual sales of $147 million in 1997.[20]

The economic advantages of renewable energy also extend far beyond the local economy. The whole country benefits. In 1997, the United States spent about $65 billion dollars outside the country to pay for fossil fuels. But as one of the world's leading manufacturers of renewable energy systems, the United States can bring in more money with the increased use of renewable energy sources around the world. Currently, for example, the United States manufactures about two-thirds of the world's photovoltaic

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[16] Union of Concerned Scientists, *Seven Powerful Solutions: 7 Ways to Switch America to Renewable Electricity*. 1999.
[17] National Renewable Energy Laboratory web site, *Jobs and the Economy*. (http://www.nrel.gov).
[18] Ibid.
[19] Steve Clemmer and Don Wichert, *The Economic Impacts of Renewable Energy Use in Wisconsin.* (Madison, WI: Wisconsin Energy Bureau, 1994).
[20] Washington Department of Community, Trade and Economic Development web site (www.energy.cted.wa.gov/ECONWReport/Default.htm)

(PV) systems. U.S manufacturers export about 70% of these PV systems, mostly to developing nations, resulting in annual export sales of more than $300 million.[21] By setting an example, Hawaii may be able to serve as a demonstration and marketing venue for companies seeking to export renewable energy technologies, especially to the Asia-Pacific region, complementing existing State sustainable technology export initiatives.

NREL reports that renewable energy is already bringing important economic benefits to the United States. For example, in 1996 the photovoltaic industry generated more that $800 million of revenues and employed 15,000 people at over 800 companies, most of them in high quality jobs, such as manufacturing, engineering, sales, installation, servicing and maintenance.[22] The biomass power generation industry employs more than 66,000 people nationwide and has created more than $1.8 billion in personal and corporate income, generating more than $460 million in federal and state taxes. Another recent study showed that the geothermal industry pays about $40 million each year to the U.S. Treasury for rent and royalties from geothermal plants. The Puna Geothermal Venture has paid approximately $3.7 million in royalties to the State of Hawaii.

Use of renewable resources often is a good financial decision. Many renewable technologies use little or no fuel and have lower operating and maintenance costs than fossil or nuclear fuels. There are many cost-effective applications for renewables, particularly distributed applications such as PV's, solar water heaters, and small wind turbines. These technologies can stand alone or can be combined with more conventional technologies such as diesel generators to provide "firm," uninterruptible power. Renewable energy can be a secure source of power especially for government facilities, allowing them to operate facilities when the power grid is down, or when power is needed in remote locations.

5. Environmental Benefits

Environmental benefits are a significant factor causing states to implement renewable energy technologies. Since they do not rely upon fossil fuels, renewable energy technologies are friendlier to the environment than conventional energy technologies.[23] Fossil fuels contribute significantly to many of the environmental problems Hawaii's face today – oil spill risks of water and soil contamination, air pollution, and greenhouse gas emissions that contribute to global climate change. Renewable energy sources contribute very little or not at all to these environmental concerns.

[21] National Renewable Energy Laboratory web site. *Jobs and the Economy*. (http://www.nrel.gov).
[22] National Renewable Energy Laboratory, *Choices for a Brighter Future: Perspectives on Renewable Energy*. September 1999, DOE/GO-1099-878.
[23] National Renewable Energy Laboratory web site. *Environmental Benefits*. (http://www.nrel.gov).

a. Oil Spill Risks of Water and Soil Contamination

Transportation of oil and oil products poses the constant risk of a spill, with subsequent damage to the environment and the economy. In 1999, over 50 million barrels of crude oil and another 8.6 million barrels of refined oil products were imported into Hawaii by sea. In addition, about 9 million barrels of refined products were shipped by barge from Oahu to neighbor islands.[24] On Oahu, large quantities of petroleum products are transported to power plants and other locations via pipelines, which have suffered accidental leaks in the past. Transportation of petroleum products on all islands by tanker truck poses the further risk of accidental spills.

Following the *Exxon Valdez* disaster in Alaska in 1989, the State of Hawaii Department of Health commissioned a study by the University of Hawaii Sea Grant College Program of the potential impacts of oil spills at sea on Hawaii. Dr. Rose Pfund led the study and edited the final report, *Oil Spills at Sea, Potential Impacts on Hawaii*.[25] The study evaluated a worst-case scenario, which would have been a major ecological disaster.

The economic costs would have been huge for such a spill. Cleanup costs alone would have been $210 to $305 million.[26] It was estimated that oil washed up on the beaches of Oahu would result in a 32% reduction in tourism in the first year and a $3.06 billion loss in revenues to the tourism industry.[27] Oahu's beaches and coral reefs would also have suffered severe environmental damage, and wildlife would have been killed in large numbers.[28]

As a result of the study, tanker operators agreed to use the wider Kauai Channel, to reduce the risk of collision and to provide more maneuvering space in event of mechanical malfunction. Soon thereafter, in reaction to the *Exxon Valdez* disaster, the Federal Oil Pollution Act of 1990 set up a planning and command structure emphasizing oil spill prevention and a response structure. Additional liability was placed on tanker operators as a strong incentive to increase safety. Hawaii's spill-prevention efforts and preparedness to deal with spills were enhanced. [29]

Hawaii remains vulnerable to oil spills. The offshore terminals are well managed, but human error or mechanical failure could lead to a major spill. For example, the *Exxon Houston* grounded near Barbers Point a few years ago. Through hard work and luck the ship was saved, and the loss of its 3.8 million gallons (90,000 barrels) of crude oil and its bunker fuel was prevented.[30]

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[24] DBEDT ERTD Data
[25] Pfund, Dr. Rose T. *Oil Spills at Sea, Potential Impacts on Hawaii.* Honolulu: University of Hawaii Sea Grant Program, 1991.
[26] Pfund, p. 35.
[27] Pfund, p. 57.
[28] Pfund, p. 69
[29] Rappa, Peter J., and Jacquelin N. Miller, Hawaii's *Readiness to Prevent and Respond to Oil Spills, Summary and Recommendations.* Honolulu: University of Hawaii Sea Grant Program, 1996, 20.
[30] Rappa, p. 24.

b. Risks to Hawaii's Air Quality

Hawaii's air quality meets federal and state environmental health standards because Hawaii's trade winds and the lack of major polluting industries reduce the buildup of air pollution over the islands.[31] Under the Clean Air Act, the United States Environmental Protection Agency set National Ambient Air Quality Standards (NAAQS) for a variety of "criteria pollutants." These include ground-level ozone, nitrogen dioxide (NO_2), particles less than 10 microns in diameter (PM10), sulfur dioxide (SO_2), carbon monoxide (CO), and lead. The State Health Department has set standards that are up to twice as stringent as the EPA criteria for most of the criteria pollutants.[32] (5-2). Nevertheless, air pollution damages Hawaii's environment.

The *Hawaii Externalities Workbook*, produced for HECO in 1997, analyzed the effects of the criteria pollutants and other air pollutants in Hawaii. Damages were estimated by quantifying emissions, determining ambient concentrations, identifying exposure to determine physical effects, and finally, monetizing damages[33]. Effects evaluated included mortality, morbidity, materials damages, and reduction of visibility.[34] As effects were specific to type of generator and its location, the calculation of monetary damages was necessarily complex. Damages from three types of pollutants were monetized. The mid-range values, which were in addition to the $43 per ton emission fee currently paid to the Department of Health, ranged from 0.002 to 0.044 cents per kWh depending upon the pollutant and the location of the power plant.[35] These values were intended for possible use in quantifying the costs of power plant air emissions in selecting among resource options for future fossil fuel generation. They demonstrate that air emissions that meet federal and State standards do have external costs that affect Hawaii's environment and economy.

By replacing fossil fuels, renewables can avert many local environmental pollutants, including those that form ground-level ozone and smog, and toxic pollutants such as mercury that pose substantial human health threats.[36]

c. Greenhouse Gas Emissions and Risks from Climate Change

The earth's weather and climate are driven by energy from the sun. Water vapor, carbon dioxide, and other gases in the atmosphere trap some of the energy from the sun, creating a natural "greenhouse effect." There is strong evidence that due to fossil fuel energy use, industrialization, and other human activities (and population growth), greenhouse gas concentrations in the atmosphere have increased. Renewable energy

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[31] Juvik, Sonia P. and James O. Juvik. *Atlas of Hawaii.* Honolulu: University of Hawaii Press, 1998, 297.
[32] Energy Research Group (ERG), Inc. et al. *Hawaii Externalities Workbook.* Honolulu: Hawaiian Electric, Inc., 1997, 5-1 to 5-2.
[33] ERG, p. 5-8.
[34] ERG, p. 5-16.
[35] ERG, p. 5-36 to 5-37.
[36] See Curtis Moore, *Dying Needlessly: Sickness and Death Due to Energy-Related Air Pollution*. Renewable Energy Policy Project Issue Brief No. 6 (College Park, MD: February 1997).

generally does not make a net contribution to greenhouse gas emissions and some technologies do not produce greenhouse gas emissions at all.

The greenhouse gases (primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons) are implicated in the global warming of the earth's atmosphere. International climate scientists of the Intergovernmental Panel on Climate Change have concluded that there is a discernible human influence on global climate from greenhouse gas emissions.

Climate is expected to continue to change in the future. By 2100, average surface temperatures could increase 1.6 to 6.3 degrees F. Sea level could increase 6 to 38 inches. Significant changes in air and ocean circulation patterns could significantly alter global climate and the ecological balance among species;

Climate Change and Atmospheric Temperature in Hawaii. Honolulu's average temperature has increased by 4.4 degrees over the last century. Rainfall has decreased by about 20% over the past 90 years. By 2100, average temperatures in Hawaii could increase by 1 to 5 degrees F in all seasons and slightly more in fall. Estimates for future rainfall are highly uncertain because reliable projections of El Niño effects have yet to be made.[37]

Climate Change and Human Health in Hawaii. The health of Hawaii's people may be negatively affected by climate change. Higher temperatures may lead to greater numbers of heat-related deaths and illnesses. Increased respiratory illnesses may result due to greater ground-level ozone. Increased use of air conditioning could increase power plant emissions and air pollution. Viral and bacterial contamination of fish and shellfish habitats could also cause human illness. Expansion of the habitat and infectivity of disease-carrying insects could increase the potential for malaria and dengue fever.[38]

Climate Change, Sea Level Rise, and Hawaii. At Honolulu, Nawiliwili, and Hilo, sea level has increased 6 to 14 inches in this century and is likely to rise another 17 to 25 inches by 2100. The expected rise in sea level could cause flooding of low-lying property, loss of coastal wetlands, beach erosion, saltwater contamination of drinking water, and damage to coastal roads and bridges. During storms, coastal areas would be increasingly vulnerable to flooding.[39]

Additional Effects of Climate Change on Hawaii. The EPA also predicts negative effects from climate change on Hawaii's water resources, agriculture and forestry, and ecosystems.[40] In addition, Hawaii's economy could be hurt if the combination of higher temperatures, changes in weather, and the effects of sea level rise on beaches make Hawaii less attractive to visitors. Adapting to sea level rise could be

[37] U.S. Environmental Protection Agency (USEPA). *Climate Change and Hawaii* (EPA-236-F-98-007e). Washington, DC: USEPA, 1998, 2.
[38] USEPA, 2-3.
[39] USEPA, 3.
[40] USEPA, 3-4.

very expensive, as it may necessitate the protection or relocation of coastal structures to prevent their damage or destruction.

Ultimately, renewable energy technologies can help us break our conventional pattern of energy use to improve the quality of our environment. Such technologies are a critical part of the solution to climate change issues. On Saturday, November 11, 2000, President Clinton released a scientific analysis that he said, “paints a sobering picture of the future” if climate change is not addressed and “makes clear that this projected global warming threatens serious harm to our environment and to our economy.”[41]

III. HOW HAWAII CAN GENERATE ELECTRICITY AT LESS COST WITH RENEWABLE ENERGY: AN ANALYSIS OF RENEWABLE PORTFOLIO OPTIONS FOR HAWAII

A. Modeling RPS Options

During the 2000 Legislative Session, a concern of some Legislators was whether a RPS would increase electricity costs to ratepayers, adding to Hawaii's already high rates. DBEDT asked GDS to determine at what percentage a RPS for Hawaii would be practical and cost effective in comparison to the current utility IRPs. GDS developed a computer spreadsheet-based cost model for the purpose of evaluating potential renewable portfolio standards. The model calculates annual costs of producing electricity to meet each utility's annual requirements for a period of twenty years (2001-2020). These annual costs were analyzed for a base case, which is comprised of existing units and unit additions included in each utility's current Integrated Resource Plan (IRP), and for four RPS scenarios. The base case scenario did not include planned renewable energy projects that had not been approved for construction as of the end of December 2000. Each scenario examined various options to achieve specified percentages of renewable energy on a statewide basis by 2010. The scenarios included:

1. 9.5% RPS by 2010 under a reference oil price forecast;
2. 10.5% RPS by 2010 under a reference oil price forecast;
3. 9.5% RPS by 2010 under a low oil price forecast; and
4. 10.5% RPS by 2010 under a low oil price forecast.

To set the RPS scenarios for modeling, GDS considered target percentages ranging from 8.0% to 10.5% on a statewide basis. The 10.5% limit was selected as a reasonably achievable goal while maintaining maximum flexibility in selecting renewable energy projects. Greater percentages of renewable energy are possible without higher statewide costs.

[41] “Clinton: Control Greenhouse Gases”, *The Atlanta Journal Constitution*, Sunday, November 12, 2000. Page A8.

In defining the new renewable energy scenarios, existing and planned renewable energy projects were supplemented by the least expensive renewable projects from the GEC *Update of Selected Cost and Performance Estimates* (Appendix 1). As the full range of scenarios proved to have lower costs than the utility IRPs, only the results of the highest two RPS -- the 9.5% and 10.5% RPS -- are presented in this report. Relatively few new renewable energy projects enabled Hawaii, on a statewide basis, to achieve a 9.5% RPS. New renewable resources must provide an additional 421.6 GWh of energy sales by 2010 in the 9.5% scenario, as compared to the base case. The total renewable energy sales target in that year, including sales from existing renewable resources is 1,063.2 GWh. The 10.5% RPS would require 533.5 GWh over the base case, with the total renewable energy sales target equal to 1,175.1 GWh. Table III-1 depicts the current base case renewable resources on each of the four Hawaii electric utility systems, and the additional systems modeled to meet the statewide 9.5% and 10.5% RPS.

Table III-1. Existing and New Renewable Resources Modeled

Utility and Renewable Resource	Energy Source	Capacity (MW)	Average Annual Generation (GWh)
HECO Base (Existing)			
H-POWER (Firm)	MSW	46.0	309.9
Kapaa Partners	LF Gas	3.2	13.7
	Base Total	49.2	323.6
HECO Planned RE Additions			
None			
	Base & Planned Total	49.2	323.6
HECO 9.5% RPS Additions			
Kahuku	Wind	30.0	85.1
	Base & 9.5% Total	79.2	408.7
HECO 10.5% RPS Additions			
Kahuku	Wind	30.0	85.1
Kaena Point	Wind	15.0	44.5
	Base & 10.5% Total	94.2	453.2
HELCO Base (Existing)			
Puna Geothermal (Firm)	Geothermal	30.0	220.0
Puueo (HELCO)	Hydro	2.3	11.8
Waiau (HELCO)	Hydro	1.1	5.8
Lalamilo Wells (HELCO)	Wind	1.8	3.9
Kamoa Wind Partners	Wind	7.0	13.6
Other Small Producers	Hydro	0.3	1.4
Wailuku	Hydro	12.0	27.1
	Base Total	54.5	283.6
HELCO Planned RE Additions			
Kahua Ranch	Wind	10.0	35.1
Puna Geothermal	Geothermal	8.0	48.3
Puna Geothermal	Geothermal	22.0	177.6
North Kohala	Wind	3.0	12.6
	Base & Planned Total	97.5	557.2
HELCO 9.5% RPS Additions			
Kahua Ranch	Wind	10.0	35.1
Puna Geothermal	Geothermal	8.0	48.3
Puna Geothermal	Geothermal	22.0	177.6
North Kohala	Wind	3.0	12.6
	Base & 9.5% Total	97.5	557.2
HELCO 10.5% RPS Additions			
Kahua Ranch	Wind	10.0	35.1
Puna Geothermal	Geothermal	8.0	48.3
Puna Geothermal	Geothermal	22.0	177.6
North Kohala	Wind	13.0	56.4
	Base & 10.5% Total	107.5	601.0

Utility and Renewable Resource	Energy Source	Capacity (MW)	Average Annual Generation (GWh)
KE Base (Existing)			
AMFAC-H	Hydro	1.5	6.9
AMFAC East	Hydro	1.3	3.4
Olokele G&R	Hydro	1.2	1.5
Gay & Robinson Steam	Bagasse	4.0	1.5
Kauai Coffee Co.	Hydro	4.7	23.7
	Base Total	12.7	37.0
KE Planned RE Additions			
None			
	Base & Planned Total	12.7	37.0
KE 9.5% RPS Additions			
North Hanapepe	Wind	10.0	26.4
	Base & 9.5% Total	22.7	63.4
KE 10.5% RPS Additions			
North Hanapepe	Wind	10.0	26.4
Port Allen	Wind	5.0	12.2
	Base & 10.5% Total	27.7	75.6
MECO Base (Existing)			
HC&S Puunene	Bagasse	12.0	38.5
HC&S	Hydro	5.9	10.7
	Base Total	17.9	49.3
MECO Planned RE Additions			
McGregor	Wind	20.0	75.6
	Base & Planned Total	37.9	124.9
MECO 9.5% RPS Additions			
McGregor	Wind	20.0	75.6
	Base & 9.5% Total	37.9	124.9
MECO 10.5% RPS Additions			
McGregor	Wind	20.0	75.6
NW Haleakala	Wind	10.0	31.4
	Base & 10.5% Total	47.9	156.3

	Capacity	**GWh**
Statewide Existing	134.3	693.5
Statewide Planned RE Additions	63.0	349.2
Statewide Existing & Planned	197.3	1,042.7
Statewide 9.5% RPS Additions	103.0	460.7
Statewide Existing & 9.5% RPS	237.3	1,154.2
Statewide 10.5% RPS Additions	143.0	592.6
Statewide Existing & 10.5% RPS	277.3	1,286.1

To allow the RPS to be met in an incremental manner, intermediate target percentages were also set. For the 9.5% RPS, intermediate target percentages were 7.0% by 2003, 7.7% by 2005, 8.4% by 2007, and 9.5% by 2010. The 10.5% RPS set intermediate targets of 7.0% by 2003, 8.0% by 2005, 9.0% by 2007, and 10.5% by 2010. In each case, the target would be met by December 31. Since relatively few new renewable projects would need to be implemented, annual percentage goals were seen as more difficult to achieve, since the addition of the projects would increase the amount of renewable energy in a “stair-step” fashion. However, wind farms and photovoltaic projects could be implemented in a modular manner if an annual increase in the RPS percentage was to be set as the standard.

For this analysis, no new renewable energy projects were added to the model after 2010. However, the results and costs were determined through 2020 and reflect the savings offered by renewable projects installed through 2010 into the future. It was envisioned that a RPS for the years after 2010 would be established in the future, when information on future developments in electricity generation technology could be incorporated.

B. Methodology

The model calculates (1) the fixed and variable operating costs of existing fossil-fueled resources, (2) the fixed and variable operating costs and the cost of capital associated with new fossil-fueled resources, and (3) the fixed and variable operating costs and the cost of capital associated with new renewable resources. The model does not calculate capital costs associated with existing generation since those costs remain the same for each scenario examined and do not affect the economic ranking of different scenarios. The model also does not calculate the cost of energy produced by existing fossil-fueled independent power producers (IPP) or the cost of energy produced by existing renewable resources, whether IPP or utility owned.

Generation from fossil-fueled IPPs and from existing renewable resources is assumed to remain at the same level for the base case and all scenarios, with no additional or reduced costs associated with the output. The one exception was Puna Geothermal Venture, which was the only existing IPP modeled to increase generation capacity. In its case, only the incremental costs of the new capacity were considered. For these reasons, annual costs produced by the model are not representative of a utility’s full annual costs. The evaluation model reproduces only the portion of a utility’s costs that are likely to change between scenarios, providing cost figures for each scenario that can be compared to one another.

Each utility’s energy sales forecast was adjusted to the generation level by adding an estimate of each system’s electricity losses. These losses are primarily in transmission and distribution and are the percentage of the total generated that is not sold to customers. Projected system energy losses were based on a five-year average of historical losses in the 1995 through 1999 period. For HECO, the percentage of system losses was modeled at 5.2%; for HELCO, 8.9%; for MECO, 6.7%; and for KE, 5.4%.

Tables III-2 shows potential projects recommended by GEC. Only a few projects were needed to meet the 9.5% RPS or the 10.5% RPS modeled.

Table III-2. Recommended Renewable Energy Projects

Technology	Island	Location	Capacity (MW)	Cost of Energy ($/kWh) in 2000	Cost of Energy ($/kWh) in 2010
Geothermal	Hawaii	***Kilauea***	*8*	$0.045	
		Kilauea (in 2005)	*22*		$0.044
Hydroelectric	Hawaii	Umauma Stream	13.8	$0.076	$0.075
	Kauai	Wailua River	6.6	$0.093	$0.092
Photovoltaics	Hawaii	N Kohola	5	$0.298	$0.205
	Oahu	Pearl Harbor	5	$0.305	$0.212
Wind	Hawaii	***Kahua Ranch***	*10*	$0.055	
		Lalamilo Wells	3	$0.044	$0.037
		Lalamilo Wells	30	$0.046	$0.038
		Lalamilo Wells	50	$0.044	$0.037
		North Kohala	5	$0.043	$0.036
		North Kohala	*10*	$0.043	$0.036
		North Kohala	15	$0.043	$0.036
	Kauai	N. Hanapepe	10	$0.067	$0.057
		Port Allen	5	$0.073	$0.062
	Maui	***McGregor Point***	*20*	$0.051	
		NW Haleakala	10	$0.055	$0.047
		NW Haleakala	30	$0.064	$0.053
		NW Haleakala	50	$0.061	$0.051
		Puunene	10	$0.077	$0.061
		Puunene	30	$0.083	$0.069
	Oahu	Kaena Point	3	$0.068	$0.057
		Kaena Point	15	$0.070	$0.058
		Kahuku	30	$0.067	$0.055
		Kahuku	50	$0.059	$0.054
		Kahuku	80	$0.069	$0.057

Note: Projects with names in bold italics are under development,
but none are currently fully approved.

Tables III-3 and III-4, on the following pages, depict the scenarios modeled for this analysis. The tables show the fossil fueled additions planned under the current utility IRPs in normal type. The planned retirements of existing fossil fueled units are preceded by a minus sign and in italics. The new renewable resources modeled are shown in bold. The renewable resources marked with an asterisk are currently in various stages in the power purchase agreement negotiation, permitting, and approval process. It should be noted that none of the planned renewable projects are yet under construction. Contracts for 10 MW of wind on the Big Island and for 20 MW of wind on Maui have been submitted to the PUC. The other projects do not have power purchase agreements. If all of the planned projects were built, together with existing renewable resources, they could produce 8.2% of generation by 2010.

Table III-3. Hawaii Utility Integrated Resource Plans and a 9.5% RPS

Year	HECO	HELCO	KE	MECO
2001		*- 3.1MW OFS* *- 25 MW IC Diesel*		
2002		40 MW DTCC Ph1&2 - 11.5 MW CT *- 13 MW IC Diesel* **10 MW Wind ***	26 MW CT	**20 MW Wind ***
2003		**3 MW Wind ***	**10 MW Wind**	
2004		**8 MW Geothermal ***		
2005		*- 7.1 MW OFS*		
2006	**30 MW Wind**	18 MW DTCC Ph 3		2.2 MW IC Diesel
2007				17 MW DTCC Ph 3 20.8 MW DTCC Ph 1
2008		**22 MW Geothermal *** *-20.8 OFS*		
2009	107 MW DTCC Ph 1	21 MW DTCC Ph 1		2.2 MW IC Diesel
2010				20.8 MW DTCC Ph 2
2011				
2012			10 MW IC Diesel	2.2 MW IC Diesel
2013	107 MW DTCC Ph 2	21 MW DTCC Ph 2		17 MW DTCC Ph 3
2014			24 MW Coal	
2015				20.8 MW DTCC Ph 1
2016	104 MW DTCC Ph 3 180 MW AFBC	18 MW DTCC Ph 3		
2017	107 MW SCCT - 180MW DTCC (IPP)	21 MW DTCC Ph 1		
2018				20.8 MW DTCC Ph 2 2.2 MW IC Diesel
2019		*- 13 MW CT*		2.2 MW IC Diesel
2020		21 MW DTCC Ph 2		

Abbreviations: DTCC - dual-train combined cycle; CT - combustion turbine; AFBC - atmospheric fluidized bed coal; SCCT - simple cycle combustion turbine; IC - internal combustion; OFS - oil-fired steam;
* indicates projects that are currently being pursued

To calculate the amount of generation and the associated costs from each resource, variable operating cost rates were determined for each resource. These rates were calculated by multiplying each resource's fuel cost, in $/MMBtu (dollars per million British thermal units), by the resource's heat rate, expressed in MMBtu/MWh. This resulted in a fuel cost rate expressed in $/MWh. Variable operation and maintenance costs, also expressed in $/MWh, were added to the fuel rate to yield a total variable operating rate. Resources were then ranked, for each year, in order of ascending variable operating costs.

Table III-4. Hawaii Utility Integrated Resource Plans and a 10.5% RPS				
Year	**HECO**	**HELCO**	**KE**	**MECO**
2001		*- 3.1 MW OFS* *- 25 MW IC Diesel*		
2002		40 MW DTCC Ph1&2 - 11.5 MW CT *- 13 MW IC Diesel* **10 MW Wind ***	26 MW CT	**20 MW Wind ***
2003		**3 MW Wind ***	**10 MW Wind**	
2004		**8 MW Geothermal ***		
2005	**30 MW Wind**	*- 7.1 MW OFS* **10 MW Wind**		
2006		18 MW DTCC Ph 3		2.2 MW IC Diesel
2007				17 MW DTCC Ph 3 20.8 MW DTCC Ph 1 **10 MW Wind**
2008		**22 MW Geothermal *** *-20.8 OFS*	**5 MW Wind**	
2009	107 MW DTCC Ph 1	21 MW DTCC Ph 1		2.2 MW IC Diesel
2010	**15 MW Wind**			20.8 MW DTCC Ph 2
2011				
2012			10 MW IC Diesel	2.2 MW IC Diesel
2013	107 MW DTCC Ph 2	21 MW DTCC Ph 2		17 MW DTCC Ph 3
2014			24 MW Coal	
2015				20.8 MW DTCC Ph 1
2016	104 MW DTCC Ph 3 180 MW AFBC	18 MW DTCC Ph 3		
2017	107 MW SCCT - 180MW DTCC (IPP)	21 MW DTCC Ph 1		
2018				20.8 MW DTCC Ph 2 2.2 MW IC Diesel
2019		*- 13 MW CT*		2.2 MW IC Diesel
2020		21 MW DTCC Ph 2		

Abbreviations: DTCC - dual-train combined cycle; CT - combustion turbine; AFBC - atmospheric fluidized bed coal; SCCT - simple cycle combustion turbine; IC - internal combustion; OFS - oil-fired steam;
* indicates projects that are currently being pursued

After adding those renewable energy projects currently in the approval process (10MW of wind at Kahua Ranch on the Big Island and 20 MW on Maui), and those under development (additional geothermal generation in 8MW and 22 MW increments by Puna Geothermal Venture and 3 MW of wind in North Kohala, the least expensive new resource was used as a source of generation first; the second least expensive resource was used next, and so forth, until each year's projected annual energy requirements were met. Variable operating costs were calculated by multiplying the variable operating rate by the amount of electricity produced by each resource.

Fixed operating and maintenance costs were determined by multiplying each resource's fixed operating rate, in $/kW per month ($/kW-Mo), by the resource's capacity and by 12 months to achieve an annual value.

The model also calculated annual carrying costs for new generating resources. These costs were determined by multiplying the installed cost of the resource by a levelized fixed charge rate. The levelized fixed charge rate is composed of (1) weighted cost of capital, (2) depreciation sinking fund component, (3) levelized annual income tax component, (4) other tax component, (5) a deduction for levelized accelerated depreciation, and (6) a deduction for levelized investment tax credits.

Each of the cost components described above -- variable O&M, fixed O&M, and new unit carrying costs -- were then summed for each year to produce a total annual cost. The sequence of annual costs was discounted, using the Gas Research Institute's (GRI) estimate of investor-owned utility weighted cost of capital (9.57% was used), to achieve a 2001 Net Present Value (NPV) of costs. NPV is the present value of future cash flows, discounted at an appropriate interest rate. The NPV for each scenario is the current amount of cash that would be required to generate, at an interest rate equal to the discount rate, an annual levelized cash flow equivalent to the annual costs associated with the RPS. The NPV is a point of reference that can be used to compare alternate scenarios. Future costs are discounted at an estimate of utility cost of capital, rather than simply added together, to assess the time value of money: costs incurred early in the life of a scenario contribute more to the NPV than costs incurred closer to the end of the study period.

Except for the geothermal generation added on the Big Island, all renewable resource additions were intermittent, or non-firm, generation. As a result, planned utility additions were not displaced with renewable resource additions. On the Big Island, the addition of the 22 MW increment modeled in 2008 allowed retirement of the Hill 5 oil-fired steam unit to be moved up from its planned 2015 retirement date.

Table III-5 summarizes the percentages of renewable electricity generation by year and by utility and statewide for each year from 2001 to 2010 under the 9.5% and 10.5% RPS.

Table III-5. Percentage of Renewable Energy by Utility under 9.5% and 10.5% RPS, 2001-2020

	HECO		HELCO		KE		MECO		Statewide	
	9.5% RPS	10.5% RPS	9.5% RPS	10.5% RPS	9.5% RPS	10.5% RPS	9.5% RPS	10.5% RPS	9.5% RPS	10.5% RPS
2001	4.1%	4.1%	28.3%	28.3%	7.5%	7.5%	4.7%	4.7%	6.62%	6.62%
2002	4.0%	4.0%	31.4%	31.4%	7.2%	7.2%	10.8%	10.8%	7.57%	7.57%
2003	4.0%	4.0%	32.2%	32.2%	11.8%	11.8%	10.5%	10.5%	7.81%	7.81%
2004	3.9%	3.9%	36.3%	36.3%	11.5%	11.5%	10.2%	10.2%	8.13%	8.13%
2005	3.9%	4.9%	35.8%	40.3%	11.8%	11.8%	10.0%	10.0%	8.03%	9.23%
2006	4.9%	4.9%	35.1%	39.5%	10.8%	10.8%	9.7%	9.7%	8.65%	9.06%
2007	4.8%	4.8%	34.4%	38.7%	10.5%	10.5%	9.4%	11.7%	8.51%	9.19%
2008	4.8%	4.8%	49.4%	53.7%	10.2%	12.2%	9.2%	11.4%	9.88%	10.65%
2009	4.7%	4.7%	48.4%	52.8%	9.9%	11.8%	8.9%	11.0%	9.71%	10.47%
2010	4.6%	5.2%	47.3%	51.4%	9.6%	11.4%	8.7%	10.7%	9.55%	10.68%
2015	4.4%	4.8%	42.0%	44.7%	8.6%	10.2%	7.4%	9.2%	8.78%	9.72%
2020	4.1%	4.5%	36.1%	38.5%	7.6%	9.1%	6.4%	8.0%	8.05%	8.91%

Note: Results do not include any new renewable energy additions that may be made after 2010

Reference Oil Price Estimates

Tables III-6 and III-7 show projected reference case fuel oil prices, by island, for the study period.

Estimated 2001 fuel prices for the Reference Cases were developed by calculating a ratio of each utility's actual 1999 oil prices by island to the statewide 1999 average price. That ratio was applied to the January through June 2000 average statewide fuel price as reported in the U.S. Energy Information Agency's *Electric Power Monthly*. These values were then escalated to 2001 using the Gas Research Institute (GRI) growth rate projection for the Pacific 2 energy demand region, which includes California and Hawaii.

The 2001 prices were reduced during the 2001 through 2003 period to reach the mid-point of OPEC's target oil price range ($25 per barrel) with adjustments for historical differences between Hawaii oil prices and average world prices. This 2003 price was then escalated through the remainder of the study period using GRI 2000 Baseline growth estimates.

Table III-6. Reference No. 6 Fuel Oil Price Forecast (Nominal $/Bbl)

					MECO		
		HECO	HELCO	KE	Maui	Lanai	Molokai
Actual:	1990	$ 25.24	$ 18.11	$ 19.60	$ 16.86	#N/A	#N/A
	1991	$ 22.78	$ 16.66	$ 15.32	$ 15.69		
	1992	$ 18.69	$ 20.95	$ 14.05	$ 15.41		
	1993	$ 20.25	$ 16.62	#N/A	$ 15.82		
	1994	$ 17.52	$ 17.59		$ 16.13		
	1995	$ 19.18	$ 19.49		$ 17.76		
	1996	$ 22.57	$ 21.42		$ 19.64		
	1997	$ 23.88	$ 21.92		$ 20.52		
	1998	$ 17.70	$ 17.55		$ 15.77		
	1999	$ 18.64	$ 19.53		$ 17.87		
Projected:	2000	$ 30.08	$ 29.58		$ 27.07		
	2005	$ 30.96	$ 30.44		$ 27.86		
	2010	$ 35.61	$ 35.01		$ 32.04		
	2015	$ 42.22	$ 41.51		$ 37.99		
	2020	$ 50.36	$ 49.51		$ 45.31		

Utility oil price forecasts were not used, as no long range forecasts since the increases in oil prices began in 1999 were available. The most recent forecast was MECO's May 1998 forecast. The reference case forecasts used here generally compare in the out years to MECO's high forecast while the low price forecasts are somewhat higher than MECO's base forecast.

Table III-7. Reference No. 2 Fuel Oil Price Forecast (Nominal $/Bbl)							
						MECO	
		HECO	HELCO	KE	Maui	Lanai	Molokai
Actual:	1990	$ 26.81	$ 31.97	$ 33.16	$ 29.63	$ 39.89	$ 35.75
	1991	$ 28.68	$ 32.55	$ 31.37	$ 31.47	$ 23.28	$ 59.36
	1992	$ 26.33	$ 38.22	$ 26.95	$ 33.29	$ 37.71	$ 30.35
	1993	$ 26.70	$ 29.78	$ 28.49	$ 28.75	$ 40.84	$ 24.60
	1994	$ 25.74	$ 27.80	$ 26.15	$ 26.52	$ 40.72	$ 28.18
	1995	$ 24.57	$ 28.38	$ 27.25	$ 27.45	$ 41.19	$ 28.77
	1996	$ 25.56	$ 33.63	$ 31.98	$ 32.91	$ 46.22	$ 32.96
	1997	$ 27.28	$ 34.03	$ 32.49	$ 33.74	$ 47.57	$ 35.31
	1998	$ 29.29	$ 27.19	$ 23.84	$ 26.59	$ 44.28	$ 28.64
	1999	$ 30.67	$ 29.28	$ 29.34	$ 30.43	$ 43.65	$ 28.76
Projected:	2000	$ 41.17	$ 45.10	$ 42.72	$ 44.67	$ 66.37	$ 45.75
	2005	$ 42.67	$ 46.73	$ 44.27	$ 46.28	$ 68.78	$ 47.41
	2010	$ 49.58	$ 54.30	$ 51.44	$ 53.78	$ 79.92	$ 55.08
	2015	$ 59.94	$ 65.65	$ 62.19	$ 65.02	$ 96.62	$ 66.60
	2020	$ 73.08	$ 80.05	$ 75.83	$ 79.28	$ 117.81	$ 81.20

Low Oil Price Estimate

The low oil price forecasts are shown in Tables III-8 and III-9. A low oil price forecast was developed that assumed the same 2001 price as the reference case and then assumed that prices decreased during 2002 and 2003, reaching the low level of OPEC's target oil price range ($22 per barrel). The 2003 price was then escalated through the remainder of the study period using GRI 2000 Baseline growth estimates. The two additional scenarios examined the 9.5% and 10.5% statewide RPS at the lower oil prices.

Table III-8. Low No. 6 Fuel Oil Price Forecast (Nominal $/Bbl)							
						MECO	
		HECO	HELCO	KE	Maui	Lanai	Molokai
Actual:	1990	$ 25.24	$ 18.11	$ 19.60	$ 16.86	#N/A	#N/A
	1991	$ 22.78	$ 16.66	$ 15.32	$ 15.69		
	1992	$ 18.69	$ 20.95	$ 14.05	$ 15.41		
	1993	$ 20.25	$ 16.62	#N/A	$ 15.82		
	1994	$ 17.52	$ 17.59		$ 16.13		
	1995	$ 19.18	$ 19.49		$ 17.76		
	1996	$ 22.57	$ 21.42		$ 19.64		
	1997	$ 23.88	$ 21.92		$ 20.52		
	1998	$ 17.70	$ 17.55		$ 15.77		
	1999	$ 18.64	$ 19.53		$ 17.87		
Projected:	2000	$ 30.08	$ 29.58		$ 27.07		
	2005	$ 27.25	$ 26.79		$ 24.51		
	2010	$ 31.34	$ 30.81		$ 28.19		
	2015	$ 37.16	$ 36.53		$ 33.43		
	2020	$ 44.32	$ 43.57		$ 39.87		

Table III-9. Low No. 2 Fuel Oil Price Forecast (Nominal $/Bbl)							
		HECO	HELCO	KE	Maui	MECO Lanai	Molokai
Actual:	1990	$ 26.81	$ 31.97	$ 33.16	$ 29.63	$ 39.89	$ 35.75
	1991	$ 28.68	$ 32.55	$ 31.37	$ 31.47	$ 23.28	$ 59.36
	1992	$ 26.33	$ 38.22	$ 26.95	$ 33.29	$ 37.71	$ 30.35
	1993	$ 26.70	$ 29.78	$ 28.49	$ 28.75	$ 40.84	$ 24.60
	1994	$ 25.74	$ 27.80	$ 26.15	$ 26.52	$ 40.72	$ 28.18
	1995	$ 24.57	$ 28.38	$ 27.25	$ 27.45	$ 41.19	$ 28.77
	1996	$ 25.56	$ 33.63	$ 31.98	$ 32.91	$ 46.22	$ 32.96
	1997	$ 27.28	$ 34.03	$ 32.49	$ 33.74	$ 47.57	$ 35.31
	1998	$ 29.29	$ 27.19	$ 23.84	$ 26.59	$ 44.28	$ 28.64
	1999	$ 30.67	$ 29.28	$ 29.34	$ 30.43	$ 43.65	$ 28.76
Projected:	2000	$ 41.17	$ 45.10	$ 42.72	$ 44.67	$ 66.37	$ 45.75
	2005	$ 37.55	$ 41.13	$ 38.96	$ 40.73	$ 60.53	$ 41.72
	2010	$ 43.63	$ 47.79	$ 45.27	$ 47.33	$ 70.33	$ 48.48
	2015	$ 52.75	$ 57.78	$ 54.73	$ 57.22	$ 85.03	$ 58.61
	2020	$ 64.31	$ 70.45	$ 66.73	$ 69.77	$ 103.68	$ 71.46

C. Model Results

The next two tables show the model results for the Reference and Low Oil Price Scenarios.

Reference Oil Price Scenario Results

Table III-10, on the next page shows the costs associated with the base case and RPS cases for each utility and for the state under reference oil price assumptions. The table also shows the NPV of savings, or in the case of HECO, the NPV of cost increases associated with the RPS cases.

As the table shows, each renewable energy portfolio scenario analyzed produced a lower NPV of electricity costs on a statewide basis compared to the base case. These results show that installation of renewable energy resources would generate a reduction in the state's electric utility costs during the 2001 through 2010 period of approximately $38.9 to $43.1 million, on a net present value basis. These savings result from the replacement of generation from existing high cost fossil units by generation from new renewable resources. The addition of renewable projects reduces costs for all of the utilities except HECO. As Table III-10 shows, HECO's costs increased by a relatively small amount -- $3.5 to $4.8 million on an NPV basis for the 2001 through 2010 period. HECO customers would begin to enjoy small per kWh savings after about 2014 as fossil fuel prices are expected to continue to rise. To put the increased costs into perspective, it should be noted that $4.8 million is 7/10 of one percent of HECO's one year operating expenses of $658 million in 1999. Although these numbers are very small, it may be more efficient for HECO to meet its RPS through credit trading, which will be discussed later in the report.

Table III-10. Savings Associated with RPS - Reference Oil Price Forecast					
9.5% RPS					
	HECO	**HELCO**	**KE**	**MECO**	**Total**
2001-2010 Costs ($000)					
NPV Base Case Costs	1,851,078	254,955	316,455	749,340	3,171,828
NPV Renewable Scenario Costs	1,854,544	241,883	312,823	723,618	3,132,868
NPV Savings (Cost)	**(3,466)**	**13,072**	**3,632**	**25,722**	**38,960**
Savings (Cost) per kWh in 2010	**$ (0.0001)**	**$ 0.0059**	**$ 0.0030**	**$ 0.0037**	**$ 0.0011**
2001-2020 Costs ($000)					
NPV Base Case Costs	3,255,754	516,072	533,010	1,323,455	5,628,291
NPV Renewable Scenario Costs	3,256,053	477,892	525,386	1,282,765	5,542,096
NPV Savings (Cost)	**(299)**	**38,180**	**7,624**	**40,690**	**86,195**
Savings (Cost) per kWh in 2020	**$ 0.0002**	**$ 0.0104**	**$ 0.0028**	**$ 0.0043**	**$ 0.0021**
10.5% RPS					
	HECO	**HELCO**	**KE**	**MECO**	**Total**
2001-2010 Costs ($000)					
NPV Base Case Costs	1,851,078	254,955	316,455	749,340	3,171,828
NPV Renewable Scenario Costs	1,855,859	239,411	312,227	721,266	3,128,763
NPV Savings (Cost)	**(4,781)**	**15,544**	**4,228**	**28,074**	**43,065**
Savings (Cost) per kWh in 2010	**$ (0.0002)**	**$ 0.0070**	**$ 0.0041**	**$ 0.0047**	**$ 0.0013**
2001-2020 Costs ($000)					
NPV Base Case Costs	3,255,754	516,072	533,010	1,323,455	5,628,291
NPV Renewable Scenario Costs	3,257,213	473,378	523,343	1,275,972	5,529,906
NPV Savings (Cost)	**(1,459)**	**42,694**	**9,667**	**47,483**	**98,385**
Savings (Cost) per kWh in 2020	**$ 0.0003**	**$ 0.0115**	**$ 0.0040**	**$ 0.0164**	**$ 0.0040**

The $38.9 to $43.1 million statewide cost savings over the 2001 to 2010 period reported by the model, were about 1.4% of all additional costs for that period. Moreover, the costs that are captured by the evaluation models are only a fraction of the actual total utility costs. As mentioned earlier in this report, only costs that could change between the base case and renewable scenarios were modeled. For instance, base case costs estimated by the model for HECO in 2001 equal approximately $262 million. As mentioned above, actual utility expenses for HECO were approximately $658 million in 1999.

The dollar savings associated with implementing renewable energy projects represent a very small percentage of total utility costs. Nevertheless, the renewable portfolio standards do offer statewide financial savings with the additional benefits of renewable energy cited above. Should oil prices be higher, the savings would increase. Naturally, if oil prices are lower, the savings would not be as great. The low oil price scenarios examined the costs in the event oil prices averaged at the low end of OPEC's target basket.

Low Oil Price Results

Table III-11 shows the results of the 9.5% and 10.5% RPS, under lower oil prices, compared to the low oil price base case.

The results of the low oil price cases show that statewide utility costs would decrease during the 2001 through 2010 period in the range of $27.8 to $30.1 million for both the 9.5% and 10.5% cases, on a net present value basis. As in the base oil price scenarios, HECO costs would increase slightly during the period, ($4.9 million to $6.7 million on an NPV basis for, for the 10-year period) while costs at the other utilities would decline. HECO customers would begin to enjoy slight per kWh savings in about 2014.

Table III-11. Savings Associated with RPS - Low Oil Price Forecast

9.5% RPS	HECO	HELCO	KE	MECO	Total
2001-2010 Costs ($000)					
NPV Base Case Costs	1,695,423	241,859	293,510	694,092	2,924,884
NPV Renewable Scenario Costs	1,700,325	233,469	291,255	672,026	2,897,075
NPV Savings (Cost)	**(4,902)**	**8,390**	**2,255**	**22,066**	**27,809**
Savings (Cost) per kWh in 2010	**$ (0.0002)**	**$ 0.0039**	**$ 0.0023**	**$ 0.0031**	**$ 0.0007**
2001-2020 Costs ($000)					
NPV Base Case Costs	2,974,630	485,824	492,901	1,220,218	5,173,573
NPV Renewable Scenario Costs	2,978,565	459,226	487,641	1,185,731	5,111,163
NPV Savings (Cost)	**(3,935)**	**26,598**	**5,260**	**34,487**	**62,410**
Savings (Cost) per kWh in 2020	**$ 0.0001**	**$ 0.0079**	**$ 0.0022**	**$ 0.0036**	**$ 0.0016**

10.5% RPS	HECO	HELCO	KE	MECO	Total
2001-2010 Costs ($000)					
NPV Base Case Costs	1,695,423	241,859	293,510	694,092	2,924,884
NPV Renewable Scenario Costs	1,702,090	231,468	290,880	670,331	2,894,769
NPV Savings (Cost)	**(6,667)**	**10,391**	**2,630**	**23,761**	**30,115**
Savings (Cost) per kWh in 2010	**$ (0.0004)**	**$ 0.0047**	**$ 0.0031**	**$ 0.0038**	**$ 0.0008**
2001-2020 Costs ($000)					
NPV Base Case Costs	2,974,630	485,824	492,901	1,220,218	5,173,573
NPV Renewable Scenario Costs	2,981,232	453,307	486,268	1,180,668	5,101,475
NPV Savings (Cost)	**(6,602)**	**32,517**	**6,633**	**39,550**	**72,098**
Savings (Cost) per kWh in 2020	**$ 0.0002**	**$ 0.0096**	**$ 0.0031**	**$ 0.0049**	**$ 0.0020**

Chart III-1 shows the statewide annual levels of savings from 2001 through 2020 for the 9.5% and 10.5% RPS under the base oil price forecast. Chart III-2 shows the 9.5% and 10.5% RPS under the low oil price forecast. The charts present differences in costs between the renewable energy portfolio scenarios and the base case.

The results of each renewable energy portfolio scenario show decreased statewide utility costs associated with the addition of new renewable resources. The decrease was caused by displacing the electricity produced by the state's existing and planned high cost fossil-fueled units with lower cost electricity produced at new renewable energy facilities. Production cost savings, while small when compared to total utility costs, were large enough to offset incremental capital costs incurred by the new renewable energy projects.

Chart III-1. Statewide Annual Savings - Reference Oil Price Scenarios

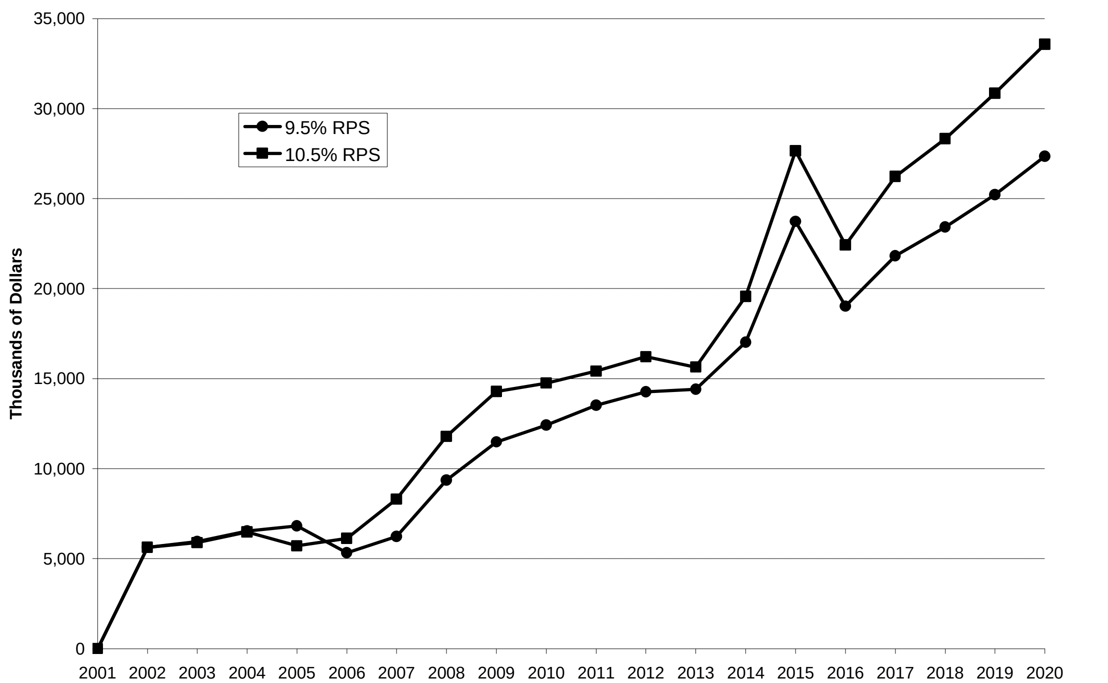
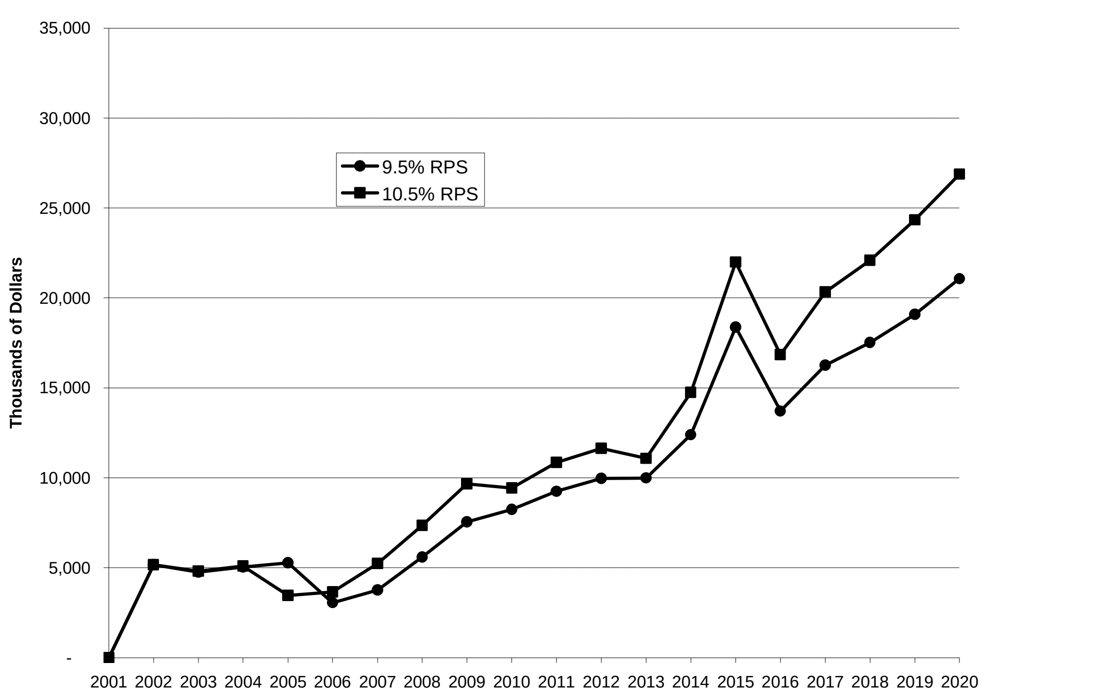


Chart III-2. Statewide Annual Savings - Low Oil Price Scenarios



IV. RECOMMENDATIONS FOR RPS IMPLEMENTATION IN HAWAII

The analyses in Section III indicate that a RPS for the year 2010 can be established in Hawaii that would provide electricity at a statewide cost lower than the combination of the existing electricity system and planned fossil fuel additions. This section offers recommendations for RPS implementation in Hawaii and covers the following topics:

- The potential role of the Legislature in mandating RPS;
- The role of the Public Utilities Commission in implementation of RPS;
- General considerations in implementing a RPS;
- Passing renewable energy savings and price stability on to the ratepayer;
- Outline of a RFP and a Standard Offer Contract for renewable energy;
- Recommendations for cost caps for renewable resources; and
- Recommendations for trading of renewable energy credits.

As a basis for these recommendations, GDS evaluated the experience of the 11 states that have adopted a RPS. Their experience is summarized in Appendix 2.

A. The Potential Role of the Hawaii Legislature in Mandating a RPS

Without serious state commitment to renewable electricity, the market share of renewable energy will stagnate or decline as has occurred in Hawaii in the 1990s. Increasing the levels of dependence on fossil fuels will reduce the performance of Hawaii's economy. Hawaii should consider enacting a RPS to remove market barriers to achieving larger goals of economic sustainability, increased renewable energy, and significant fuel diversity.

Experience in other states has shown that broad legislative support has been necessary in order to have successful implementation of a RPS. While the PUC could enact a RPS through regulations, our research indicates that the broader support of the legislature has been necessary in most RPS states to have successful implementation and acceptance by key market actors.

While our analysis has shown significant economic benefits to the State and its ratepayers from renewable energy, government intervention is necessary, in part, because the cost of electricity generated by fossil fuels does not include most of the costs of damage such generation causes to the environment and human health. Furthermore, the market does not assign value to the public benefits of renewable energy. As cited in Section II, the predominant public benefits are environmental benefits, including reduced risk of oil spills, reduced air pollution, and greenhouse gas emission mitigation. Renewable energy deployment also provides substantial society-wide benefits via price stability and reliability benefits from the existence of multiple and distributed fuel sources; readiness benefits in the event of sudden fuel price spikes or fuel supply disruption; technology development potential, including export potential; and the benefits provided by conserving fossil resources for future generations. Most importantly, the status quo has resulted in plans by Hawaii's electric utilities to add more fossil fuel generation, reducing the proportion of electricity produced from renewable resources over the planning period. This analysis shows that renewable energy projects at the levels analyzed in the scenarios (up to 10.5% by 2010) can be attained cost effectively.

As noted above, eleven states have implemented Renewable Portfolio Standards or renewable energy set-asides. Nine of the eleven states enacted a RPS through legislation while two (Arizona and Pennsylvania) implemented a RPS through orders from their Public Utilities Commissions. Table IV-1 below summarizes the authority for RPS in each of these eleven states.

Table IV-1. Implementing RPS in Other States

State	Authority for RPS
Arizona	The Arizona Corporation Commission approved the "Solar and Environmentally Friendly Portfolio Standard" 4/26/2000.
Connecticut	Law – H.5005 (revised in 1999)
Iowa	Law: Alternate Energy Production Law 1983, revised 1991.
Maine	Law: LD1804 and Public Law chapter 316 Regulations final Docket 97-584, law revised in May 1999
Massachusetts	Law: Chapter 164 of the Acts of 1997
Minnesota	Law: Radioactive Waste Management Facility Authorization (1994) Minn. Stat. 216B.2423 And MN PUC Order Docket E-002/RP-98-32
Nevada	Nevada law enacted in 1997 for RPS – Deregulation: Assembly Bill 366[42]
New Jersey	Restructuring law passed in January 1999
Pennsylvania	Being addressed by PUC in individual utility restructuring cases.
Texas	Senate Bill 7[43] (Draft regulations were published in 10/99) Regulations were adopted in December 1999.
Wisconsin	Legislated through Act 9 (legislation passed November 1, 1999)

In Hawaii, as in most states, legislation may be the most effective means to create a RPS. The legislature can craft legislation that will achieve the desired level of renewable energy in a manner that is most acceptable to all stakeholders. The Hawaii RPS will have the highest chance of success if it is actively supported by all major participants in the energy marketplace, including the electric utilities and large

[42] See www.leg.state.nv.us
[43] See www.capitol.state.tx.us/cgi-bin/tlo

consumers, as well as the general public.

B. The Role of the Public Utilities Commission in Implementation of a RPS

Hawaii's Public Utilities Commission has the statutory authority to develop rules to regulate the utilities. If a RPS were enacted, the Commission would be responsible for developing rules for RPS implementation and for oversight of the implementation process. The Commission would also be responsible for enforcing the rules for RPS implementation. The success or failure of a RPS is highly dependent on the rules for implementation, and the enforcement of those rules. As the saying says, “the devil is in the details.” This will be especially true in Hawaii, given the separate nature of the electric grids on the individual islands and likelihood that some utilities will have more opportunity to provide the needed increase in renewable energy than other utilities.

C. General Considerations in Implementing a RPS

To date, there is little actual experience with the functioning of a Renewable Portfolio Standard. Of the 11 states that currently have or had renewable energy requirements, the earliest start was in 2000 with most programs being implemented between 2001 and 2003. However, several important lessons learned in the development and implementation of a RPS have been identified in the literature and in the interviews with states.

If a Renewable Portfolio Standard is to be successful and have the desired result, the details of the program must be carefully constructed. The following lessons learned should be considered in development of a RPS for Hawaii.

1. Establish a Realistic Set of Goals

Development of a Renewable Portfolio Standard of necessity requires making informed tradeoffs between different program designs. In order to make these tradeoffs, a realistic set of goals for the program must be established. Efforts should be focused on technologies or markets where state policies might have a lasting impact.

This report was based upon the latest identification and characterization of potential renewable resources in Hawaii. The costs of these resources have been updated. The analysis summarized above shows that the recommended goals of 9.5% and 10.0% are realistic.

2. Applicability to the Utilities

The RPS recommended in this Analysis would be a statewide standard. In some utilities' service territories, notably HECO's, the availability of renewable resources may not be sufficient to meet the RPS with current technologies in a cost-effective manner.

To deal with this situation, two options are suggested.

Option One would be for implementing rules to require each utility company to meet the RPS. Under this option, the HECO utilities -- HECO, HELCO, and MECO -- would together meet the RPS as a percentage of their combined generation in whatever manner would be the least costly. Kauai Electric, a separate company, would meet the RPS independently. It appears that there are sufficient renewable resources on Kauai to accomplish this. The main advantage of this approach is simplicity, in that a formal credit trading mechanism would not be needed.

Option Two would require each utility -- HECO, HELCO, KE, and MECO -- to independently meet the RPS either through deployment of renewable energy resources or through acquisition of renewable energy credits from one or more of the other Hawaii utilities. This option would require a formal credit trading mechanism as outlined in Section F, below.

3. Strive for "Market Transformation"

It is unlikely that state policies will last forever. Successful policies will be those that strive to "transform" markets and create a continuing demand for renewables after the policy is removed. A successful RPS will demonstrate the benefits of renewable energy and will contribute to further reduction in costs and technological improvements.

4. Identify Eligible Projects and Technology

Varied approaches have been taken to identify technologies to be included in the RPS. Most policies include wind, solar, geothermal and some forms of biomass. Treatment of other renewables such as hydroelectricity, fuel cells and MSW as well as the distinction between existing and new projects varies between states. Support should generally be provided to technologies that provide substantial and incremental public benefits.

We recommend that the technologies for Hawaii include wind, hydroelectricity, geothermal, solar photovoltaic and solar thermal, and biomass. Biomass would include agricultural and forest product wastes, landfill gas, waste-to-energy, and other organic wastes. Ocean thermal energy conversion (OTEC) and wave power would also qualify as renewable energy sources. They were not included in the modeling discussed in Section III due to their currently high costs.

5. Resource Diversity

Renewable energy should include a mix of technologies with diverse characteristics, market needs, costs, and social benefits.

6. Policy Stability and Duration

Short duration policies can create immediate markets for renewables but can be destabilizing, making the renewable industry vulnerable to changing political forces. With restructuring there is a tendency for renewables policies to become part of much larger negotiations. Policy duration and stability are especially important for RPS where facilities will be brought on-line under the expectation of continued support. Without some certainty in the length and stability of the policy, new renewable generators will need to amortize their capital costs over a shortened period, increasing the near-term cost. Therefore, continuity in the scope, scale, and duration of a renewables policy should be sought.

Hawaii's RPS should cover a period of ten years and should be evaluated every five years for a new ten year period. This will allow updating and revision of goals based on new cost and performance information.

D. Passing Renewable Energy Savings and Price Stability on to the Ratepayer

Previously in Hawaii, most renewable energy power purchase agreements were tied to utility costs that are significantly influenced by the cost of fossil fuel. To allow renewable energy to provide cost savings in the face of expected oil prices, smarter ways for paying for renewable energy need to be developed. Otherwise, Hawaii will have little monetary gain from deployment of renewable energy resources. If oil prices skyrocket, for example, the price for renewable energy would also increase if it were tied to the price of oil. Such a linkage could result in windfall profits to developers of renewable energy projects. Therefore it will be important to develop innovative contract terms for renewable energy projects that provide a fair rate of return to renewable energy project developers without linking payments to future cost trends for fossil fuels. Since most renewable energy projects have little or no on-going fuel costs, it can be argued that contract payments need not emphasize possible escalation in fuel prices.

In developing its recommendations for an RPS policy for Hawaii, GDS Associates, based on discussions with staff at the Lawrence Livermore National Laboratory (LBL) of the U.S. Department of Energy,[44] recommends that the State of Hawaii should consider requiring utilities that conduct RFPs for renewable energy to sign "fixed price" contracts with renewable energy suppliers.[45] This could be accomplished in a number of ways, including:

1. specifying cost caps for renewable energy;
2. specifying a maximum allowable rate of return for renewable energy

[44] GDS Telephone call with Ryan Wiser of LBL, November 22, 2000.
[45] GDS notes that Enron/Zond signed such a fixed price power purchase agreement with HELCO recently for a 10 MW wind energy project at Kahua Ranch. As of December 2000, the agreement was awaiting Public Utilities Commission approval.

projects; or

3. prohibiting tying contracts for renewable energy to fossil fuel prices.

This approach will allow developers to earn a profit for delivery of successful renewable energy projects, and will allow the citizens of Hawaii to realize the real economic benefits of renewable energy projects.

E. Outline of the Elements of a RFP and a Standard Offer Contract for Renewable Energy

By using a standardized request for proposals (RFP) and a standard offer contract, the acquisition of renewable energy can be greatly simplified and the expense to both the utility and renewable energy developer can be reduced. In addition, such a contract can be designed to break the link with volatile fossil fuel costs by use of appropriate pricing language.

GDS collected samples of renewable energy RFPs that are in use by some of the states with RPS.[46] GDS recommends that the following language should be included in the "pricing section" of RFPs for renewable energy to ensure that pricing is not tied to fossil fuels. The same language should be included in ensuing contracts with winning bidders.

1. Pricing

"Bidders should provide pricing information based on the respondent's best estimate of the expected "all-in" fixed and variable costs of power to be generated from each renewable resource, stated as $/kW of fixed costs, if applicable; $/kWh of variable costs; and $/kWh of total costs. All anticipated operations and maintenance expenses should be included in these costs. In addition to initial fixed and variable components, price estimates should include any escalation factors that would be applied, if any. Escalation may not be tied to prices of fossil fuels. All pricing formulas must be properly and completely specified. Buyer's payments will be linked to performance. The buyer will make payment to the host bidder only for actual, verified output from the renewable resource delivered to the buyer's system. Preference will be given to bids that do not include escalation factors and are fixed price contracts."

2. Elements for Recommended Bid Evaluation Criteria for RFPs

GDS recommends that the following type of language be included in RFPs for renewable energy to ensure that bidders understand fully how proposals will be evaluated:

[46] These RFPs are available from GDS upon request.

"The buyer intends to evaluate the responses to this RFP to identify qualified respondents and projects. The evaluation criteria for proposed renewable energy projects will consider the following factors:

- project timing (10 points)
- experience and capability of the seller (10 points)
- location of the resource (10 points)
- nature of the resource (10 points)
- absence of price escalation factors (10 points)
- the overall cost of power (30 points)
- the degree to which the bid is a fixed price proposal (10 points)
- any other factors which the buyer may consider relevant to meeting its goals (10 points)

Initial evaluation will focus on resources capable of meeting the buyer's RPS goals and project life cycle costs per kWh provided. Based on the nature of the responses and the evaluation process, the buyer will elect, at its option, to initiate negotiations with qualified respondents, to reject all proposals, or to proceed with a new RFP for renewable resources. The buyer reserves the right to cancel this RFP or to reject all proposals at its sole discretion at any time. The buyer intends to meet with selected bidders within two weeks of notice to seller that an award is to be made, and to award contracts within four weeks of initial notification of award to seller. The buyer anticipates that contract negotiations will be completed by no later than four weeks after initial notification. The information included in the response is considered confidential and will be used solely for evaluation purposes."

F. Cost Caps for Renewable Energy Resources

Cost caps can be an effective mechanism to ensure that the State of Hawaii does not pay too much for renewable energy. Hawaii could tie either the enactment of a RPS, or tie potential increases in the RPS itself, to a provision that either retail rates will not go up any higher than a certain percentage, or that the busbar costs of new renewable projects will not exceed some certain level. Nevada is considering a proposal that would phase out or terminate their RPS goal if electricity rates would increase by more than 3% because of the RPS. One concern that has been expressed is it is all too easy to "game" this rule by saying rates will skyrocket anyway, and unless fairly extensive documentation is required, that would be the end of a RPS requirement. But, this proposal is still worth consideration.

An important principle to keep in mind is to make the cost cap higher than the market price of renewables, so it only is activated if costs increase to an unexpectedly high number. Otherwise, it may become necessary for the credit administrator (GDS recommends that the Hawaii PUC have this role) to take this "market interference" approach too often, and it may become too muddled and bureaucratic. One criticism of the Clinton Administration's proposed RPS was that the cost cap was set too low at $15/MWh. (See EIA's *Annual Energy Outlook 2000* for an interesting analysis of this issue.)

G. Penalties for Non-Compliance

Many states have penalties that are assessed on utilities that do not meet their RPS. HB 1883 proposed the following language, "Failure to produce and receive approval of the required number of renewable energy credits shall result in a penalty which shall be equal to three times the market value of a renewable energy credit for each credit that is not produced." If a credit trading system, discussed in the following section is not adopted, another form of penalty may be required.

A strong penalty provision is critical to ensure compliance with the RPS. Texas, for example, has a penalty mechanism where violators pay the $50/MWh or twice the average market value of credits, whichever is less. Wisconsin, on the other hand, requires court action for a penalty of $50,000 to $500,000 to be imposed. For a large utility, paying the penalty in Wisconsin may be more economical than complying with the RPS. Nevada has a very harsh penalty of operating license revocation for RPS non-compliance.[47]

Penalties for non-compliance with a RPS can effectively serve as a cost cap, since retailers may simply opt to pay a penalty rather than buy renewable energy credits that are more costly than paying the penalty. Arizona, for instance, had a penalty of $300/MWh at one point, but because their RPS at the time was all solar, at least one utility was talking about simply paying the penalty, in the belief that new solar would be more expensive than $300/MWh.

GDS recommends that the PUC be empowered through legislation to impose an administrative penalty against a qualified electric utility company for violating the RPS requirement. Failure to produce and receive approval of the required number of renewable energy credits should result in a penalty. If a renewable energy credit trading mechanism is established, GDS recommends that the penalty be a multiple of the market value of a renewable energy credit for each credit that is not produced. In the event each company is required to meet the RPS and a trading mechanism is not employed, the penalty could be some multiple of the cost of the fuel used that would have been displaced by the percentage of renewable energy not provided by the company.

Table IV-2 summarizes Cost Caps and Penalties in RPS Policies. None of the

[47] Porter, Kevin, Ryan Wiser. *A Status Report on the Design and Implementation of State Renewable Portfolio Standards and Systems Benefits Charge Policies*, National Renewable Energy Laboratory and Lawrence Berkeley National Laboratory, April 2000.

states with a RPS in place have explicit cost caps for renewable energy. For further information on cost caps included in State RPS programs, see the following publication on the NREL web site: *Comparing State Portfolio Standards and System-Benefit Charges Under Restructuring.*[48]

TABLE IV-2. SUMMARY OF COST CAPS AND PENALTIES IN RPS POLICIES

State	Cost Cap	Penalties
Arizona	No explicit cap but penalty acts as de facto cap	30 cents/kWh starting in 2004. Proceeds go to solar electric fund to finance solar facilities for schools, cities, counties or state agencies
Connecticut	No explicit cap	Must meet RPS to be licensed; flexible penalties for failing to comply with license conditions include license revocation or suspension, or a prohibition from accepting new customers or civil penalties
Maine	No explicit cap but penalty and flexibility conditions should reduce cost fluctuations	Variety of possible sanctions at discretion of Commission including license revocation, monetary penalties, and other appropriate penalties; allows voluntary payment into renewables R&D fund to avoid license revocation.
Massachusetts	Not included in legislation	Considered multitude of possible penalties for non-compliance, but no decisions have yet been made. Imposition of penalties may require subsequent legislative approval, but considering imposition of financial sanctions through arrangement with PUC. Penalty could be set at three times average market value of new renewables generation, or at a fixed amount that may be periodically revised.
Nevada	Not included in legislation	Compliance required to maintain license; penalties include license suspension and revocation; exploring other approaches
New Jersey	None included in legislation or draft rule	Draft RPS rule would require non-complying retailers to purchase the requirement amount of renewables and possibly face financial penalties and/or license revocation or suspension
New Mexico	No explicit cap	Not Addressed
Pennsylvania	Unspecified	Unspecified
Texas	None explicit but implicit cap of 5 cents/kWh for renewable energy credits	Penalty for noncompliance is the lesser of 5 cents/kWh or 200% of the average market value of renewable energy credits; under certain circumstances, penalty may not be assessed.
Wisconsin	None	Penalty of $5,000 - $500,000 is allowed in legislation.

H. Trading of Renewable Energy Resources Credits

Based upon the data collected and analyzed to date, the ability of each utility to meet the statewide RPS varies. If each of Hawaii's four electric utilities were to be required to independently meet a statewide RPS, a renewable energy credit trading mechanism to ensure that the overall statewide RPS targets would be met can be considered. The precise details of this mechanism will need to be developed with additional public input from interested stakeholders and enacted by the PUC. This section outlines the components of such a mechanism.

[48] http://www.nrel.gov/analysis/emaa/rps-sbc082300.pdf

As proposed in HB 1883, which was considered by the 2000 Legislature, renewable portfolio standards could be met through the establishment of renewable energy credits, which are tradable certificates of proof that one kilowatt-hour of electricity has been generated by a renewable-fueled source. Credits are denominated in kilowatt-hours (kWh) and are a separate commodity from the power itself. The renewable portfolio standards would require each electric utility to demonstrate, through ownership of credits, that they have supported an amount of renewable energy generation equivalent to the established RPS percentage of their total annual kilowatt-hour sales. For example, if the RPS was set at ten and a half per cent, and a generator sells one hundred thousand kilowatt-hours in a given year, the generator would need to possess ten thousand five hundred credits at the end of that year.

The utilities would make all decisions about how to comply with this requirement, including the type of renewable energy to acquire, which technologies to use, what renewable developers to do business with, what price to pay, and which contract terms to agree to. The utilities would decide for themselves whether to invest in renewable energy projects and generate their own credits, enter into long-term contracts to purchase renewable energy from developers, enter into long-term contracts to purchase credits or renewable power along with credits, or simply to purchase credits. The credit system provides compliance flexibility and avoids the need to "track electrons." Because the RPS applies equally to all utilities, they are competitively neutral.

The study provided by GEC provides a listing of each of Hawaii utility's different options to add renewable energy for its system. For various reasons, one or more of Hawaii's utilities may not be able to achieve the 9.5% or 10.5% RPS by 2010, or it may not be able to meet an established intermediate milestone. Other utilities, certainly HELCO, will be able to exceed the proposed RPS. To accommodate these differences, GDS recommends that the Hawaii consider a renewable energy credit trading mechanism. If there is a system of credit trading for renewable energy, it will be possible to establish a maximum credit price for renewable energy. That price represents the market price of renewables. If retail suppliers on any of the four utility systems have trouble procuring enough renewable energy credits to meet the RPS, they can buy proxy credits at the pre-established price from the credit administrator. GDS recommends that the PUC serve as the administrator of the credit trading system. The administrator, in turn, takes the proxy credit sale proceeds and goes into the market to buy as many credits as possible until the proceeds are exhausted.

As an alternative to a credit trading arrangement, Hawaii's utility companies could be required to meet the RPS on a by-company rather than by-utility basis. In this case, HECO, HELCO, and MECO would jointly meet the RPS and KE would separately meet the RPS. This appears feasible at least through 2010 and would greatly simplify the process. Therefore, this is the recommended course of action.

APPENDIX 1.

UPDATE OF SELECTED COST AND PERFORMANCE ESTIMATES

Renewable Energy Resource Assessment and Development Program

November 2000

Prepared for:

State of Hawaii
Department of Business, Economic Development & Tourism
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SECTION 1. INTRODUCTION

In 1995, Global Energy Concepts (GEC), formerly RLA Consulting, conducted a *Renewable Energy Resource Assessment and Development Program* for the State of Hawaii Department of Business, Economic Development and Tourism (DBED&T). The work included the development of cost and performance estimates for potential renewable energy projects on each island. Since that time, DBED&T has used this information to develop and support their position for various legislative and regulatory efforts. DBED&T has requested that GEC, working as a subcontractor to GDS Associates, Inc., update the cost and performance estimates for a selected number of projects to reflect changes in the technology and development potential of the projects evaluated in the 1995 effort.

The *Renewable Energy Resource Assessment and Development Program* was part of the 1995 Hawaii Energy Strategy (HES), a multi-faceted program intended to produce an integrated energy strategy for the State of Hawaii. In Phase 1 of the program, suitable locations with development potential for renewable energy projects were identified and defined on each of the major Hawaiian Islands. The emphasis for project identification was on utility-scale, grid-connected renewable energy projects. In Phase 2, resource supply curves were developed based on the cost and performance of the potential projects identified in the first phase. The cost and performance estimates were based on 1995 renewable energy conversion systems and realistic future projections with consideration of all the necessary components of a project, including permitting, shipping, equipment integration, construction, operation, and maintenance. More than 200 potential projects were described in the 1995 report. This report provides an update of the cost and performance estimates for a subset of those projects. These selected projects focus on the renewable energy technologies and project locations that appear to be most economic and promising for application in Hawaii in the next decade. Although other projects are certainly possible, these projects offer near-term opportunities and 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 1995 report; some are similar with slight variation in location, 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 in the project. For this effort, technologies were limited to wind, photovoltaics, hydroelectric, municipal and organic waste, and geothermal. For each potential project, costs and performance were estimated 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 for each of the projects evaluated in this program, 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 bring a project from its conception stage to successful operation in Hawaii. The results are realistic estimates bounded by optimistic and conservative ranges to represent the uncertainty associated with the technology development or the resource availability.

For some of the wind projects updated in this report, a number of possible project sizes were evaluated. The size and number of projects evaluated at each location was based on several factors. The size and characteristics of the land parcel available for potential development was the first consideration. The capacity of the existing transmission lines was the next criteria used to define potential project sizes. For most locations, transmission upgrades are required for projects above a certain size. For this update, it was assumed 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. The size of the utility grid was also a consideration. For islands other than Oahu, projects larger than 30 MW may be difficult to develop because of the size of the existing utility grid and the projected demand growth. As a result, 30 MW project sizes were evaluated for sites in which other constraints did not define the size.

For most technologies, two conceptual plant designs were developed. One design was based on plant components that are commercially available for installation within the next year (current technology). The other design was based on components that are realistically expected to be commercially deployed within the next decade (future technology).

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

Project performance estimates are based on the conceptual plant designs, potential project sizes, and the best available resource data. 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 Plant Costs and Initial Costs. Total Plant Costs are made up of four components: process capital, general facilities capital, engineering and overhead, and project contingency. Each of the components of the Total Plant Costs and Initial Costs is discussed in more detail below:

> ***Process Capital*** is the total constructed cost of all on-site processing and generating units, including all direct and indirect construction costs. The estimates 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., that are required for plant operations, but do not directly contribute to the production of the energy end product.
>
> ***Engineering and Overhead*** is assumed to be 7% of the process capital.
>
> ***Project Contingency*** is assumed to be 8% 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 plant. Initial or start-up costs include the equivalent of 25% of the annual operating costs, 2% of Total Plant Costs (a simplifying assumption from the EPRI TAG) to account for any last minute changes, and the capital required for inventory of spare parts, fuel on hand, or other miscellaneous expenses.

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

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

In order to adjust U.S. mainland costs to Hawaii, cost indexes were applied based on the R. S. Means Building Construction Cost Data, 2000. This document specified indexes for materials and installation of various construction-related projects for use in adjusting costs between U.S. cities. Additional cost information on labor rates, equipment rental, and construction processes was obtained from companies involved with projects on each of the Hawaiian Islands and this information was applied as appropriate.

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 basis are outlined below.

Wind

Technology Status: Wind energy is a technology that has been commercially deployed on a large-scale basis for two decades. Technology advances continue to improve the performance and reliability as well as reduce the cost of the technology. Since the 1995 study, wind energy has made dramatic increases in deployment; currently more than 13,000 MW are installed worldwide. With increased deployment, the reliability and performance has also improved. For this study, current cost and performance estimates are meant to reflect wind technology that is currently being bid for projects that will be installed in the 2000 time frame in the US.

Future cost and performance estimates were scaled from current estimates based on technology advances currently under development and expected to be achievable in the next ten years.

Since wind energy is currently one of the more economic of the renewable energy options, most of the wind projects evaluated in the 1995 study are included in this 2000 update. A few projects have been modified to reflect current development plans underway on Hawaii and Maui, and one project has been dropped because the landowner is pursuing alternative land use plans.

Performance Assumptions: Estimates of the wind resource at specific sites were based on the same historical 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 15% to 24%. Energy losses account for blade soiling, array effects, control inefficiencies, turbulence, downtime, and line losses. The losses are slightly less than assumed in the 1995 study because a larger turbine size was assumed for installation in 2000; therefore, a lower level of array losses are anticipated.

- A wind turbine representative of commercially available technology was used for cost and performance estimates. It was assumed that the turbine had a 50 m rotor diameter and was mounted on a 50 m tower. For future technology, a turbine with a 70 m rotor diameter mounted on an 80 m tower was assumed.

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 expressed in terms of 2000 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 to account for larger spacing between turbines and ease of construction.

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

- Turbine and tower costs were varied to reflect larger production run discounts. A discount was applied to the equipment costs for projects 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, there is limited experience with large-scale photovoltaic installations for bulk electricity generation. However, there are multiple demonstration projects installed throughout the US 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.

Although a significant number of PV projects were evaluated in the 1995 study, only two were chosen to update for 2000. These two projects are representative of what could be done in a number of different locations in Hawaii; however, the costs have not gone down as significantly as predicted and limited effort was expended on updating the cost and performance at every site. Remote, or off-grid PV applications are also very promising and are discussed in Appendix B.

Performance Assumptions: The solar resource data used for the PV performance estimates in 1995 were also used for the 2000 updates. The variations between optimistic, nominal, and conservative performance estimates account for the uncertainty in the resource data. In addition, the following assumptions were made:

- Only fixed (and not tracking) PV systems were updated for 2000. Fixed systems were assumed to face due south at a 15-degree tilt angle.

- Current technology assumes a 13.5% efficient crystalline module and future technology assumes a 17% efficient crystalline module at 1000 W/m2 and 20 degrees C.

- Energy losses and the array field layouts are assumed to be the same as in 1995.

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 not gone down as significantly as predicted in 1995, but remain at $3.60/watt in 2000. Power Conditioning Unit (PCU) costs have decreased from the earlier estimates. Array structure costs have increased slightly.

- 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. There are few appreciable differences between the types of projects that were considered in 1995 and those that could be installed in 2000. New projects are expected to have slightly lower operation and maintenance costs than existing project resulting from semi-automatic operating strategies and improvements in designs.

Completing the permitting and environmental requirements of hydroelectric projects continues to be viewed as difficult in Hawaii (and elsewhere) due to the high value placed on natural resources and competing uses. Both projects considered in this study are run-of-the-river rather than storage type projects.

Performance Assumptions: No changes were made in the performance predictions for the two hydroelectric projects for 2000. 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 to maintain 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.

Biomass

Technology Status: There are a number of methods for converting biomass to energy. In recent years, there have been a number of changes in the agricultural sector in Hawaii. Several of the sugar plantations have closed or reduced operations and the amount of energy generated by biomass associated with these facilities has been drastically reduced. Due to the uncertainty associated with the agricultural production and biomass energy industry in Hawaii new technology data sheets were not developed for the 2000 update. Biomass fuels, considered in the 1995, were also not updated because of the focus on electricity generation options.

There is currently a municipal solid waste (MSW) facility operating in Oahu. It is unlikely that the refuse stream on Oahu will increase significantly enough in the near future to justify an additional facility of this type. On the smallest islands in Hawaii, there is also insufficient refuse to justify a facility of this type. However, MSW projects may be viable on the islands of Kauai and Maui in the next few years.

Geothermal

Technology Status: Geothermal energy conversion from high-temperature (>150 degrees C) water-dominated resource areas is a mature technology that has been commercially deployed since the 1960s. While research and development efforts are still underway, the technology is not expected to drastically change in the next 5-10 years.

Cost and performance estimates in this study reflect conventional flash-plant technology. One such geothermal facility is currently operating on the Big Island in the Kilauea east rift zone. The potential geothermal projects included in this report represent only an increase in the capacity of this existing project. An 8 MW topping plant, currently proposed by the project developer, is included as a current option and a further 22 MW expansion at the same location is considered as a future option. Although there is significant potential for further geothermal facilities on the Big Island, these two projects are representative of near-term opportunities.

Performance Assumptions: The Kilauea east rift zone is known to be 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 plant's productivity are the efficiency losses associated with corrosivity, scaling, and equipment required to account for gas concentrations. The following basic assumptions were made:

- A normal amount of site and well variation is assumed relative to the experience of the existing power plant location.

- The exact plant configuration would depend on the resource condition, but is almost certain to include flashing, condensation, and reinjection.

- The 8 MW expansion is considered a topping unit that will draw off one of the existing resource wells. The output of this facility is dependent on the strength of the resource.

- 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.

SECTION 3. RENEWABLE ENERGY PROJECTS INCLUDED IN THE 2000 UPDATE

Table 1 lists the current and future projects for which Year 2000 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*.

TABLE 1. Current and Future Projects Included in the 2000 Update

Technology	Island	Location	Capacity MW
Geothermal	Hawaii	Kilauea [1]	8, 22
Hydroelectric	Hawaii	Umauma Stream	13.8
	Kauai	Wailua River	6.6
Photovoltaic	Hawaii	N Kohola	5
	Oahu	Pearl Harbor	5
Wind	Hawaii	Kahua Ranch [2]	10
		Lalamilo Wells	3, 30, 50
		North Kohala	5, 15
	Kauai	N. Hanapepe	10
		Port Allen	5
	Maui	McGregor Point [2]	20
		NW Haleakala	10, 30, 50
		Puunene	10, 30
	Oahu	Kaena Point	3, 15
		Kahuku	30, 50, 80

[1] The 8 MW project is a topping unit that could be added to the existing 30 MW facility. The 22 MW project could be installed in 2005 as a separate power plant at the same location.

[2] Future projects were not evaluated because actual projects are currently under development which will preclude additional projects at these locations.

Although no project sites are included in the database for either Lanai or Molokai, renewable energy has potential on these islands for use in small-scale applications. 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. The National Renewable Energy Laboratory (NREL) prepared the Appendix B technology descriptions. 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 2 and 3 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. Although these numbers are not intended to represent contract prices or absolute values, they provide a consistent means by which to compare the various renewable energy projects considered in this study.

TABLE 2. Current Projects – 2000

Technology	Island	Location	Capacity MW	COE $/kWh
Geothermal	Hawaii	Kilauea	8	$0.045
Hydroelectric	Hawaii	Umauma Stream	13.8	$0.076
	Kauai	Wailua River	6.6	$0.093
Photovoltaics	Hawaii	N Kohola	5	$0.298
	Oahu	Pearl Harbor	5	$0.305
Wind	Hawaii	Kahua Ranch	10	$0.055
		Lalamilo Wells	3	$0.044
		Lalamilo Wells	30	$0.046
		Lalamilo Wells	50	$0.044
		North Kohala	5	$0.043
		North Kohala	15	$0.043
	Kauai	N. Hanapepe	10	$0.067
		Port Allen	5	$0.073
	Maui	McGregor Point	20	$0.051
		NW Haleakala	10	$0.055
		NW Haleakala	30	$0.064
		NW Haleakala	50	$0.061
		Puunene	10	$0.077
		Puunene	30	$0.083
	Oahu	Kaena Point	3	$0.068
		Kaena Point	15	$0.070
		Kahuku	30	$0.067
		Kahuku	50	$0.059
		Kahuku	80	$0.069

TABLE 3. Future Projects – 2010

Technology	Island	Location	Capacity MW	COE $/kWh
Geothermal	Hawaii	Kilauea (in 2005)	22	$0.044
Hydroelectric	Hawaii	Umauma Stream	13.8	$0.075
	Kauai	Wailua River	6.6	$0.092
Photovoltaics	Hawaii	N Kohola	5	$0.205
	Oahu	Pearl Harbor	5	$0.212
Wind	Hawaii	Lalamilo Wells	3	$0.037
		Lalamilo Wells	30	$0.038
		Lalamilo Wells	50	$0.037
		North Kohala	5	$0.036
		North Kohala	15	$0.036
	Kauai	N. Hanapepe	10	$0.057
		Port Allen	5	$0.062
	Maui	NW Haleakala	10	$0.047
		NW Haleakala	30	$0.053
		NW Haleakala	50	$0.051
		Puunene	10	$0.061
		Puunene	30	$0.069
	Oahu	Kaena Point	3	$0.057
		Kaena Point	15	$0.058
		Kahuku	30	$0.055
		Kahuku	50	$0.054
		Kahuku	80	$0.057

SECTION 4. 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.)	22.06	Extent (# of units)	4
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	16,162	14,692	13,223
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	14,539	12,483	10,573
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,623,950	2,677,500	2,731,050
Foundations	228,458	233,120	237,782
Assembly & Checkout	78,400	80,000	81,600
Electrical Infrastructure	260,876	266,200	271,524
Sub-Station	147,000	150,000	153,000
Overseas Shipping	98,000	100,000	102,000
Legal Fees & Permitting	284,778	355,973	444,966
General Facilities			
Roads & Grading	36,027	36,762	37,497
Control System	23,520	24,000	24,480
Control Buildings	9,408	9,600	9,792
Central Building	10,710	11,900	14,875
Engineering & Overhead	260,502	270,395	281,535
Project Contingency	324,930	337,236	351,208
Initial Costs	221,885	227,275	232,932
SUB-TOTAL	$ 4,608,444	$ 4,779,961	$ 4,974,241
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	26,170	24,966	23,261
Fixed O&M	27,473	27,750	28,028
Land Lease	5,016	5,280	5,544
FIRST YEAR O&M	$ 58,659	$ 57,996	$ 56,833

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.)	22.06	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	161,616	146,924	132,231
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	131,088	111,825	94,031
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,990,000	25,500,000	26,010,000
Foundations	2,284,576	2,331,200	2,377,824
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,608,760	2,662,000	2,715,240
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	346,673	433,341	541,676
General Facilities			
Roads & Grading	311,140	317,490	323,840
Control System	235,200	240,000	244,800
Control Buildings	94,080	96,000	97,920
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,342,481	2,395,858	2,450,752
Project Contingency	2,922,204	2,989,239	3,059,204
Initial Costs	2,073,412	2,112,880	2,151,932
SUB-TOTAL	$41,523,166	$42,467,608	$43,451,187
TRANSMISSION			
Cost of Upgrade	1,960,000	2,000,000	2,040,000
ANNUAL EXPENSES			
Variable O&M	235,958	223,649	206,868
Fixed O&M	274,725	277,500	280,275
Land Lease	50,160	52,800	55,440
FIRST YEAR O&M	$ 560,843	$ 553,949	$ 542,583

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.)	22.06	Extent (# of units)	66
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	266,667	242,424	218,182
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	216,295	184,511	155,151
CAPITAL COSTS			
Process Capital			
Turbines & Towers	40,408,830	41,233,500	42,058,170
Foundations	3,769,550	3,846,480	3,923,410
Assembly & Checkout	1,293,600	1,320,000	1,346,400
Electrical Infrastructure	4,304,454	4,392,300	4,480,146
Sub-Station	2,450,000	2,500,000	2,550,000
Overseas Shipping	1,617,000	1,650,000	1,683,000
Legal Fees & Permitting	389,813	487,266	609,083
General Facilities			
Roads & Grading	509,833	520,238	530,643
Control System	388,080	396,000	403,920
Control Buildings	155,232	158,400	161,568
Central Building	80,640	89,600	112,000
Engineering & Overhead	3,796,327	3,880,068	3,965,515
Project Contingency	4,733,069	4,837,908	4,945,908
Initial Costs	3,359,130	3,422,055	3,483,891
SUB-TOTAL	$67,255,559	$68,733,816	$70,253,653
TRANSMISSION			
Cost of Upgrade	1,960,000	2,000,000	2,040,000
ANNUAL EXPENSES			
Variable O&M	389,331	369,022	341,331
Fixed O&M	453,296	457,875	462,454
Land Lease	82,764	87,120	91,476
FIRST YEAR O&M	$ 925,392	$ 914,017	$ 895,261

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.)	23.43	Extent (# of units)	6
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	25,961	23,601	21,241
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	23,354	20,051	16,984
CAPITAL COSTS			
Process Capital			
Turbines & Towers	3,935,925	4,016,250	4,096,575
Foundations	376,955	384,648	392,341
Assembly & Checkout	117,600	120,000	122,400
Electrical Infrastructure	391,314	399,300	407,286
Sub-Station	245,000	250,000	255,000
Overseas Shipping	147,000	150,000	153,000
Legal Fees & Permitting	288,543	360,679	450,848
General Facilities			
Roads & Grading	57,861	59,042	60,223
Control System	35,280	36,000	36,720
Control Buildings	14,112	14,400	14,688
Central Building	37,620	41,800	52,250
Engineering & Overhead	385,164	397,661	411,422
Project Contingency	482,590	498,382	516,220
Initial Costs	336,195	343,827	351,744
SUB-TOTAL	$ 6,851,159	$ 7,071,989	$ 7,320,717
TRANSMISSION			
Cost of Upgrade	352,800	360,000	367,200
ANNUAL EXPENSES			
Variable O&M	42,038	40,102	37,365
Fixed O&M	41,209	41,625	42,041
Land Lease	22,572	23,760	24,948
FIRST YEAR O&M	$ 105,819	$ 105,487	$ 104,354

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: **Wind**

Island Hawaii Location North Kohala Project Code: ________ (leave blank)

Capacity (MW)	15	Stage (current/future)	Current
Resource (mph, avg.)	23.43	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	86,535	78,669	70,802
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	77,848	66,837	56,614
CAPITAL COSTS			
Process Capital			
Turbines & Towers	12,495,000	12,750,000	13,005,000
Foundations	1,256,517	1,282,160	1,307,803
Assembly & Checkout	392,000	400,000	408,000
Electrical Infrastructure	1,304,380	1,331,000	1,357,620
Sub-Station	735,000	750,000	765,000
Overseas Shipping	490,000	500,000	510,000
Legal Fees & Permitting	312,509	390,636	488,296
General Facilities			
Roads & Grading	180,134	183,810	187,486
Control System	117,600	120,000	122,400
Control Buildings	47,040	48,000	48,960
Central Building	80,640	89,600	112,000
Engineering & Overhead	1,188,978	1,218,266	1,248,920
Project Contingency	1,487,984	1,525,078	1,564,919
Initial Costs	1,061,149	1,082,310	1,103,463
SUB-TOTAL	$21,148,931	$21,670,860	$22,229,867
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	140,126	133,675	124,550
Fixed O&M	137,363	138,750	140,138
Land Lease	75,240	79,200	83,160
FIRST YEAR O&M	$ 352,729	$ 351,625	$ 347,848

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)	Current
Resource (mph, avg.)	18.3	Extent (# of units)	13
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	45,448	41,316	37,185
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	40,885	35,103	29,733
CAPITAL COSTS			
Process Capital			
Turbines & Towers	9,077,250	9,262,500	9,447,750
Foundations	742,487	757,640	772,793
Assembly & Checkout	254,800	260,000	265,200
Electrical Infrastructure	847,847	865,150	882,453
Sub-Station	490,000	500,000	510,000
Overseas Shipping	318,500	325,000	331,500
Legal Fees & Permitting	314,428	393,035	491,294
General Facilities			
Roads & Grading	104,805	106,944	109,083
Control System	76,440	78,000	79,560
Control Buildings	30,576	31,200	31,824
Central Building	80,640	89,600	112,000
Engineering & Overhead	843,172	865,433	889,069
Project Contingency	1,054,476	1,353,450	1,113,802
Initial Costs	753,213	965,060	785,307
SUB-TOTAL	$14,988,634	$15,853,013	$15,821,635
TRANSMISSION			
Cost of Upgrade	784,000	800,000	816,000
ANNUAL EXPENSES			
Variable O&M	73,593	81,000	65,413
Fixed O&M	89,286	90,188	91,089
Land Lease	47,500	50,000	52,500
FIRST YEAR O&M	$ 210,379	$ 221,188	$ 209,002

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: **Wind**

Island	Maui	Location	McGregor Point	Project Code: (leave blank)	

Capacity (MW)	20.25	Stage (current/future)	Current
Resource (mph, avg.)	20	Extent (# of units)	27
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	97,862	88,965	80,069
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	88,037	75,585	64,023
CAPITAL COSTS			
Process Capital			
Turbines & Towers	18,852,750	19,237,500	19,622,250
Foundations	1,696,298	1,730,916	1,765,534
Assembly & Checkout	529,200	540,000	550,800
Electrical Infrastructure	2,347,884	2,395,800	2,443,716
Sub-Station	992,250	1,012,500	1,032,750
Overseas Shipping	661,500	675,000	688,500
Legal Fees & Permitting	356,304	445,379	556,724
General Facilities			
Roads & Grading	319,874	326,402	332,930
Control System	158,760	162,000	165,240
Control Buildings	63,504	64,800	66,096
Central Building	80,640	89,600	112,000
Engineering & Overhead	1,780,533	1,822,597	1,866,219
Project Contingency	2,227,160	2,850,249	2,336,221
Initial Costs	1,567,606	2,004,598	1,630,040
SUB-TOTAL	$31,634,262	$33,357,341	$33,169,021
TRANSMISSION			
Cost of Upgrade	686,000	700,000	714,000
ANNUAL EXPENSES			
Variable O&M	158,467	146,250	140,852
Fixed O&M	185,439	187,313	189,186
Land Lease	71,250	75,000	78,750
FIRST YEAR O&M	$ 415,156	$ 408,563	$ 408,787

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.)	17.42	Extent (# of units)	13
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	38,586	35,078	31,570
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	34,712	29,803	25,244
CAPITAL COSTS			
Process Capital			
Turbines & Towers	8,121,750	8,287,500	8,453,250
Foundations	742,487	757,640	772,793
Assembly & Checkout	254,800	260,000	265,200
Electrical Infrastructure	847,847	865,150	882,453
Sub-Station	490,000	500,000	510,000
Overseas Shipping	318,500	325,000	331,500
Legal Fees & Permitting	300,202	375,253	469,066
General Facilities			
Roads & Grading	104,805	106,944	109,083
Control System	76,440	78,000	79,560
Control Buildings	30,576	31,200	31,824
Central Building	80,640	89,600	112,000
Engineering & Overhead	775,291	795,938	817,898
Project Contingency	971,467	997,778	1,026,770
Initial Costs	683,617	698,219	713,167
SUB-TOTAL	$13,798,422	$14,168,221	$14,574,564
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	62,482	59,605	55,537
Fixed O&M	89,286	90,188	91,089
Land Lease	48,906	51,480	54,054
FIRST YEAR O&M	$ 200,674	$ 201,273	$ 200,680

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.)	17.42	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	118,726	107,933	97,139
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	96,300	82,148	69,077
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,990,000	25,500,000	26,010,000
Foundations	2,284,576	2,331,200	2,377,824
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,608,760	2,662,000	2,715,240
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	346,673	433,341	541,676
General Facilities			
Roads & Grading	311,140	317,490	323,840
Control System	235,200	240,000	244,800
Control Buildings	94,080	96,000	97,920
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,342,481	2,395,858	2,450,752
Project Contingency	2,922,204	2,989,239	3,059,204
Initial Costs	2,082,837	2,124,442	2,165,927
SUB-TOTAL	$41,532,591	$42,479,169	$43,465,183
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	173,339	164,297	151,969
Fixed O&M	274,725	277,500	280,275
Land Lease	150,480	158,400	166,320
FIRST YEAR O&M	$ 598,544	$ 600,197	$ 598,564

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.)	17.42	Extent (# of units)	66
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	195,898	178,089	160,280
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	158,894	135,545	113,976
CAPITAL COSTS			
Process Capital			
Turbines & Towers	40,408,830	41,233,500	42,058,170
Foundations	3,769,550	3,846,480	3,923,410
Assembly & Checkout	1,293,600	1,320,000	1,346,400
Electrical Infrastructure	4,304,454	4,392,300	4,480,146
Sub-Station	2,450,000	2,500,000	2,550,000
Overseas Shipping	1,617,000	1,650,000	1,683,000
Legal Fees & Permitting	389,813	487,266	609,083
General Facilities			
Roads & Grading	509,833	520,238	530,643
Control System	388,080	396,000	403,920
Control Buildings	155,232	158,400	161,568
Central Building	80,640	89,600	112,000
Engineering & Overhead	3,796,327	3,880,068	3,965,515
Project Contingency	4,733,069	4,837,908	4,945,908
Initial Costs	3,374,682	3,441,132	3,506,983
SUB-TOTAL	$67,271,110	$68,752,893	$70,276,745
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	286,010	271,090	250,748
Fixed O&M	453,296	457,875	462,454
Land Lease	248,292	261,360	274,428
FIRST YEAR O&M	$ 987,598	$ 990,325	$ 987,630

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.)	14.65	Extent (# of units)	13
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	28,829	26,208	23,587
Expected Losses (%)	15%	20%	25%
Net Energy (MWh/yr)	24,404	20,875	17,608
CAPITAL COSTS			
Process Capital			
Turbines & Towers	8,121,750	8,287,500	8,453,250
Foundations	816,736	833,404	850,072
Assembly & Checkout	254,800	260,000	265,200
Electrical Infrastructure	847,847	865,150	882,453
Sub-Station	490,000	500,000	510,000
Overseas Shipping	318,500	325,000	331,500
Legal Fees & Permitting	300,383	375,478	469,348
General Facilities			
Roads & Grading	118,997	121,426	123,855
Control System	76,440	78,000	79,560
Control Buildings	30,576	31,200	31,824
Central Building	80,640	89,600	112,000
Engineering & Overhead	780,501	801,257	823,328
Project Contingency	978,974	1,005,441	1,034,591
Initial Costs	672,600	686,985	701,805
SUB-TOTAL	$13,888,743	$14,260,441	$14,668,785
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	43,927	41,750	38,738
Fixed O&M	89,286	90,188	91,089
Land Lease	16,302	17,160	18,018
FIRST YEAR O&M	$ 149,515	$ 149,098	$ 147,845

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.)	14.65	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	88,705	80,641	72,577
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	71,949	61,376	51,610
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,990,000	25,500,000	26,010,000
Foundations	2,513,034	2,564,320	2,615,606
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,608,760	2,662,000	2,715,240
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	347,228	434,035	542,544
General Facilities			
Roads & Grading	354,809	362,050	369,291
Control System	235,200	240,000	244,800
Control Buildings	94,080	96,000	97,920
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,358,512	2,412,225	2,467,457
Project Contingency	2,945,301	3,012,818	3,083,269
Initial Costs	2,052,253	2,093,223	2,134,282
SUB-TOTAL	$41,813,816	$42,766,271	$43,758,409
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	129,508	122,752	113,541
Fixed O&M	274,725	277,500	280,275
Land Lease	50,160	52,800	55,440
FIRST YEAR O&M	$ 454,393	$ 453,052	$ 449,256

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.)	17.53	Extent (# of units)	40
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	110,500	100,454	90,409
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	89,627	76,456	64,290
CAPITAL COSTS			
Process Capital			
Turbines & Towers	24,990,000	25,500,000	26,010,000
Foundations	2,513,034	2,564,320	2,615,606
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,956,595	3,016,933	3,077,272
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	348,033	435,041	543,801
General Facilities			
Roads & Grading	401,389	409,581	417,772
Control System	235,200	240,000	244,800
Control Buildings	94,080	96,000	97,920
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,382,916	2,437,141	2,492,888
Project Contingency	2,978,871	3,047,089	3,118,245
Initial Costs	2,093,193	2,135,233	2,177,212
SUB-TOTAL	$42,307,950	$43,270,938	$44,273,516
TRANSMISSION			
Cost of Upgrade	882,000	900,000	918,000
ANNUAL EXPENSES			
Variable O&M	161,329	152,913	141,439
Fixed O&M	274,725	277,500	280,275
Land Lease	150,480	158,400	166,320
FIRST YEAR O&M	$ 586,534	$ 588,813	$ 588,034

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.)	17.53	Extent (# of units)	66
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	182,324	165,749	149,174
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	164,020	140,822	119,281
CAPITAL COSTS			
Process Capital			
Turbines & Towers	40,408,830	41,233,500	42,058,170
Foundations	4,146,505	4,231,128	4,315,751
Assembly & Checkout	1,293,600	1,320,000	1,346,400
Electrical Infrastructure	4,878,381	4,977,940	5,077,499
Sub-Station	2,450,000	2,500,000	2,550,000
Overseas Shipping	1,617,000	1,650,000	1,683,000
Legal Fees & Permitting	392,058	490,072	612,590
General Facilities			
Roads & Grading	658,744	672,188	685,631
Control System	388,080	396,000	403,920
Control Buildings	155,232	158,400	161,568
Central Building	80,640	89,600	112,000
Engineering & Overhead	3,863,046	3,948,185	4,035,039
Project Contingency	4,826,569	4,933,361	5,043,325
Initial Costs	3,399,029	3,466,271	3,532,864
SUB-TOTAL	$68,557,715	$70,066,645	$71,617,757
TRANSMISSION			
Cost of Upgrade	1,960,000	2,000,000	2,040,000
ANNUAL EXPENSES			
Variable O&M	295,237	281,644	262,418
Fixed O&M	453,296	457,875	462,454
Land Lease	248,292	261,360	274,428
FIRST YEAR O&M	$ 996,825	$ 1,000,879	$ 999,300

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.)	17.53	Extent (# of units)	106
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	292,824	266,203	239,583
Expected Losses (%)	19%	24%	29%
Net Energy (MWh/yr)	237,512	202,609	170,369
CAPITAL COSTS			
Process Capital			
Turbines & Towers	64,899,030	66,223,500	67,547,970
Foundations	6,659,539	6,795,448	6,931,357
Assembly & Checkout	2,077,600	2,120,000	2,162,400
Electrical Infrastructure	7,834,976	7,994,873	8,154,771
Sub-Station	3,920,000	4,000,000	4,080,000
Overseas Shipping	2,597,000	2,650,000	2,703,000
Legal Fees & Permitting	461,280	576,600	720,750
General Facilities			
Roads & Grading	1,054,674	1,076,198	1,097,722
Control System	623,280	636,000	648,720
Control Buildings	249,312	254,400	259,488
Central Building	80,640	89,600	112,000
Engineering & Overhead	6,191,460	6,325,229	6,461,017
Project Contingency	7,731,903	7,899,348	8,070,336
Initial Costs	5,442,677	5,549,596	5,655,334
SUB-TOTAL	$109,823,371	$112,190,793	$114,604,865
TRANSMISSION			
Cost of Upgrade	8,820,000	9,000,000	9,180,000
ANNUAL EXPENSES			
Variable O&M	427,521	405,219	374,812
Fixed O&M	728,021	735,375	742,729
Land Lease	398,772	419,760	440,748
FIRST YEAR O&M	$ 1,554,314	$ 1,560,354	$ 1,558,289

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.)	16.74	Extent (# of units)	4
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	10,508	9,553	8,598
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	9,453	8,116	6,875
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,623,950	2,677,500	2,731,050
Foundations	228,458	233,120	237,782
Assembly & Checkout	78,400	80,000	81,600
Electrical Infrastructure	347,835	354,933	362,032
Sub-Station	147,000	150,000	153,000
Overseas Shipping	98,000	100,000	102,000
Legal Fees & Permitting	284,976	356,221	445,276
General Facilities			
Roads & Grading	46,216	47,159	48,103
Control System	23,520	24,000	24,480
Control Buildings	9,408	9,600	9,792
Central Building	10,710	11,900	14,875
Engineering & Overhead	266,603	276,624	287,892
Project Contingency	333,206	345,685	359,831
Initial Costs	221,543	227,079	232,926
SUB-TOTAL	$ 4,719,825	$ 4,893,821	$ 5,090,638
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	17,016	16,233	15,125
Fixed O&M	27,473	27,750	28,028
Land Lease	5,016	5,280	5,544
FIRST YEAR O&M	$ 49,505	$ 49,263	$ 48,696

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.)	16.74	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	52,542	47,765	42,989
Expected Losses (%)	15%	20%	25%
Net Energy (MWh/yr)	44,477	38,046	32,092
CAPITAL COSTS			
Process Capital			
Turbines & Towers	12,495,000	12,750,000	13,005,000
Foundations	1,142,288	1,165,600	1,188,912
Assembly & Checkout	392,000	400,000	408,000
Electrical Infrastructure	1,739,173	1,774,667	1,810,160
Sub-Station	735,000	750,000	765,000
Overseas Shipping	490,000	500,000	510,000
Legal Fees & Permitting	313,223	391,528	489,411
General Facilities			
Roads & Grading	209,246	213,517	217,787
Control System	117,600	120,000	122,400
Control Buildings	47,040	48,000	48,960
Central Building	80,640	89,600	112,000
Engineering & Overhead	1,211,468	1,241,226	1,272,354
Project Contingency	1,517,814	1,555,531	1,595,999
Initial Costs	1,040,600	1,061,869	1,083,417
SUB-TOTAL	$21,531,092	$22,061,537	$22,629,399
TRANSMISSION			
Cost of Upgrade	1,470,000	1,500,000	1,530,000
ANNUAL EXPENSES			
Variable O&M	80,059	76,091	70,601
Fixed O&M	137,363	138,750	140,138
Land Lease	25,080	26,400	27,720
FIRST YEAR O&M	$ 242,501	$ 241,241	$ 238,459

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)	Current
Resource (mph, avg.)	17.08	Extent (# of units)	13
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	32,657	29,688	26,719
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	29,378	25,223	21,365
CAPITAL COSTS			
Process Capital			
Turbines & Towers	8,121,750	8,287,500	8,453,250
Foundations	816,736	833,404	850,072
Assembly & Checkout	254,800	260,000	265,200
Electrical Infrastructure	1,130,463	1,153,533	1,176,604
Sub-Station	490,000	500,000	510,000
Overseas Shipping	318,500	325,000	331,500
Legal Fees & Permitting	301,037	376,296	470,370
General Facilities			
Roads & Grading	156,844	160,045	163,246
Control System	76,440	78,000	79,560
Control Buildings	30,576	31,200	31,824
Central Building	80,640	89,600	112,000
Engineering & Overhead	800,330	821,501	843,990
Project Contingency	1,006,249	1,033,286	1,063,009
Initial Costs	689,411	704,295	719,572
SUB-TOTAL	$14,273,775	$14,653,660	$15,070,196
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	52,881	50,447	47,003
Fixed O&M	89,286	90,188	91,089
Land Lease	48,906	51,480	54,054
FIRST YEAR O&M	$ 191,073	$ 192,114	$ 192,146

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.)	15.8	Extent (# of units)	6
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	13,945	12,677	11,410
Expected Losses (%)	10%	15%	20%
Net Energy (MWh/yr)	12,545	10,771	9,123
CAPITAL COSTS			
Process Capital			
Turbines & Towers	3,935,925	4,016,250	4,096,575
Foundations	342,686	349,680	356,674
Assembly & Checkout	117,600	120,000	122,400
Electrical Infrastructure	391,314	399,300	407,286
Sub-Station	245,000	250,000	255,000
Overseas Shipping	147,000	150,000	153,000
Legal Fees & Permitting	288,460	360,574	450,718
General Facilities			
Roads & Grading	51,311	52,358	53,405
Control System	35,280	36,000	36,720
Control Buildings	14,112	14,400	14,688
Central Building	37,620	41,800	52,250
Engineering & Overhead	382,759	395,206	408,916
Project Contingency	479,125	494,846	512,611
Initial Costs	326,751	334,391	342,410
SUB-TOTAL	$ 6,794,943	$ 7,014,806	$ 7,262,652
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	22,581	21,541	20,071
Fixed O&M	41,209	41,625	42,041
Land Lease	7,524	7,920	8,316
FIRST YEAR O&M	$ 71,314	$ 71,086	$ 70,428

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)	Future
Resource (mph, avg.)	22.06	Extent (# of units)	2
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	18,586	16,896	15,207
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	16,969	14,582	12,363
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,409,750	2,677,500	3,079,125
Foundations	182,766	186,496	190,226
Assembly & Checkout	78,400	80,000	81,600
Electrical Infrastructure	242,876	247,832	252,789
Sub-Station	147,000	150,000	153,000
Overseas Shipping	98,000	100,000	102,000
Legal Fees & Permitting	284,607	355,759	444,698
General Facilities			
Roads & Grading	29,913	30,524	31,134
Control System	11,760	12,000	12,240
Control Buildings	7,056	7,200	7,344
Central Building	10,710	11,900	14,875
Engineering & Overhead	241,038	270,145	301,241
Project Contingency	299,510	330,348	373,622
Initial Costs	205,765	222,664	255,980
SUB-TOTAL	$ 4,249,151	$ 4,682,367	$ 5,299,874
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	29,934	28,580	26,655
Fixed O&M	26,923	13,598	27,467
Land Lease	4,028	4,240	4,452
FIRST YEAR O&M	$ 60,885	$ 46,418	$ 58,574

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)	Future
Resource (mph, avg.)	22.06	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	185,859	168,962	152,066
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	155,565	132,974	112,074
CAPITAL COSTS			
Process Capital			
Turbines & Towers	22,950,000	25,500,000	29,325,000
Foundations	1,827,661	1,864,960	1,902,259
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,428,756	2,478,322	2,527,888
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	344,960	431,200	539,000
General Facilities			
Roads & Grading	250,004	255,106	260,208
Control System	117,600	120,000	122,400
Control Buildings	70,560	72,000	73,440
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,154,976	2,387,783	2,636,210
Project Contingency	2,676,733	2,919,918	3,269,152
Initial Costs	1,919,565	2,106,975	2,371,019
SUB-TOTAL	$38,055,454	$41,525,864	$46,504,577
TRANSMISSION			
Cost of Upgrade	1,960,000	2,000,000	2,040,000
ANNUAL EXPENSES			
Variable O&M	274,416	260,630	241,631
Fixed O&M	269,231	135,975	274,670
Land Lease	40,280	42,400	44,520
FIRST YEAR O&M	$ 583,926	$ 439,005	$ 560,820

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)	Future
Resource (mph, avg.)	22.06	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	306,667	278,788	250,909
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	256,682	219,408	184,921
CAPITAL COSTS			
Process Capital			
Turbines & Towers	37,110,150	41,233,500	47,418,525
Foundations	3,015,640	3,077,184	3,138,728
Assembly & Checkout	1,293,600	1,320,000	1,346,400
Electrical Infrastructure	4,007,447	4,089,231	4,171,016
Sub-Station	2,450,000	2,500,000	2,550,000
Overseas Shipping	1,617,000	1,650,000	1,683,000
Legal Fees & Permitting	386,987	483,734	604,668
General Facilities			
Roads & Grading	408,958	417,304	425,650
Control System	194,040	198,000	201,960
Control Buildings	116,424	118,800	121,176
Central Building	80,640	89,600	112,000
Engineering & Overhead	3,491,658	3,862,415	4,263,864
Project Contingency	4,333,804	4,723,181	5,282,959
Initial Costs	3,109,995	3,386,311	3,837,727
SUB-TOTAL	$61,616,343	$67,149,261	$75,157,672
TRANSMISSION			
Cost of Upgrade	1,960,000	2,000,000	2,040,000
ANNUAL EXPENSES			
Variable O&M	452,786	430,039	398,690
Fixed O&M	444,230	224,359	453,205
Land Lease	66,462	69,960	73,458
FIRST YEAR O&M	$ 963,479	$ 724,357	$ 925,353

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)	Future
Resource (mph, avg.)	23.43	Extent (# of units)	3
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	29,855	27,141	24,427
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	27,258	23,423	19,859
CAPITAL COSTS			
Process Capital			
Turbines & Towers	3,614,625	4,016,250	4,618,688
Foundations	301,564	307,718	313,873
Assembly & Checkout	117,600	120,000	122,400
Electrical Infrastructure	364,313	371,748	379,183
Sub-Station	245,000	250,000	255,000
Overseas Shipping	147,000	150,000	153,000
Legal Fees & Permitting	288,269	360,337	450,421
General Facilities			
Roads & Grading	47,381	48,348	49,315
Control System	17,640	18,000	18,360
Control Buildings	10,584	10,800	11,016
Central Building	37,620	41,800	52,250
Engineering & Overhead	355,486	398,650	440,480
Project Contingency	443,767	487,492	549,119
Initial Costs	311,212	343,259	385,417
SUB-TOTAL	$ 6,302,061	$ 6,924,402	$ 7,798,520
TRANSMISSION			
Cost of Upgrade	352,800	360,000	367,200
ANNUAL EXPENSES			
Variable O&M	48,083	45,909	42,817
Fixed O&M	40,385	20,396	41,200
Land Lease	18,126	19,080	20,034
FIRST YEAR O&M	$ 106,594	$ 85,385	$ 104,051

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: **Wind**

Island Hawaii Location North Kohala Project Code: ____________ (leave blank)

Capacity (MW)	15	Stage (current/future)	Future
Resource (mph, avg.)	23.43	Extent (# of units)	10
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	99,516	90,469	81,422
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	90,860	78,077	66,198
CAPITAL COSTS			
Process Capital			
Turbines & Towers	11,475,000	12,750,000	14,662,500
Foundations	1,005,213	1,025,728	1,046,243
Assembly & Checkout	392,000	400,000	408,000
Electrical Infrastructure	1,214,378	1,239,161	1,263,944
Sub-Station	735,000	750,000	765,000
Overseas Shipping	490,000	500,000	510,000
Legal Fees & Permitting	311,597	389,497	486,871
General Facilities			
Roads & Grading	145,199	148,162	151,125
Control System	58,800	60,000	61,200
Control Buildings	35,280	36,000	36,720
Central Building	80,640	89,600	112,000
Engineering & Overhead	1,093,623	1,217,170	1,339,979
Project Contingency	1,362,938	1,488,425	1,667,487
Initial Costs	981,440	1,116,417	1,209,906
SUB-TOTAL	$19,381,109	$21,210,161	$23,720,975
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	160,277	153,030	142,723
Fixed O&M	134,615	67,988	137,335
Land Lease	60,420	63,600	66,780
FIRST YEAR O&M	$ 355,313	$ 284,618	$ 346,838

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)	Future
Resource (mph, avg.)	17.42	Extent (# of units)	6
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	40,960	37,237	33,513
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	37,398	32,136	27,247
CAPITAL COSTS			
Process Capital			
Turbines & Towers	6,885,000	7,650,000	8,797,500
Foundations	548,298	559,488	570,678
Assembly & Checkout	235,200	240,000	244,800
Electrical Infrastructure	728,627	743,497	758,367
Sub-Station	490,000	500,000	510,000
Overseas Shipping	294,000	300,000	306,000
Legal Fees & Permitting	298,041	372,552	465,689
General Facilities			
Roads & Grading	78,822	80,431	82,039
Control System	35,280	36,000	36,720
Control Buildings	21,168	21,600	22,032
Central Building	80,640	89,600	112,000
Engineering & Overhead	663,542	741,522	815,712
Project Contingency	828,689	906,775	1,017,723
Initial Costs	583,899	629,848	723,295
SUB-TOTAL	$11,771,207	$12,871,312	$14,462,555
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	65,970	62,987	58,744
Fixed O&M	80,769	40,793	82,401
Land Lease	36,252	38,160	40,068
FIRST YEAR O&M	$ 182,991	$ 141,939	$ 181,213

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)	Future
Resource (mph, avg.)	17.42	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	136,535	124,123	111,710
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	114,281	97,685	82,331
CAPITAL COSTS			
Process Capital			
Turbines & Towers	22,950,000	25,500,000	29,325,000
Foundations	1,827,661	1,864,960	1,902,259
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,428,756	2,478,322	2,527,888
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	344,960	431,200	539,000
General Facilities			
Roads & Grading	250,004	255,106	260,208
Control System	117,600	120,000	122,400
Control Buildings	70,560	72,000	73,440
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,154,976	2,387,783	2,636,210
Project Contingency	2,676,733	2,919,918	3,269,152
Initial Costs	1,921,499	2,130,883	2,377,248
SUB-TOTAL	$38,057,388	$41,549,772	$46,510,806
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	201,591	191,463	177,506
Fixed O&M	269,231	135,975	274,670
Land Lease	120,840	127,200	133,560
FIRST YEAR O&M	$ 591,661	$ 454,638	$ 585,736

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)	Future
Resource (mph, avg.)	17.42	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	225,283	204,802	184,322
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	188,563	161,181	135,846
CAPITAL COSTS			
Process Capital			
Turbines & Towers	37,110,150	41,233,500	47,418,525
Foundations	3,015,640	3,077,184	3,138,728
Assembly & Checkout	1,293,600	1,320,000	1,346,400
Electrical Infrastructure	4,007,447	4,089,231	4,171,016
Sub-Station	2,450,000	2,500,000	2,550,000
Overseas Shipping	1,617,000	1,650,000	1,683,000
Legal Fees & Permitting	386,987	483,734	604,668
General Facilities			
Roads & Grading	408,958	417,304	425,650
Control System	194,040	198,000	201,960
Control Buildings	116,424	118,800	121,176
Central Building	80,640	89,600	112,000
Engineering & Overhead	3,491,658	3,862,415	4,263,864
Project Contingency	4,333,804	4,723,181	5,282,959
Initial Costs	3,113,186	3,412,760	3,848,005
SUB-TOTAL	$61,619,533	$67,175,710	$75,167,950
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	332,625	315,914	292,885
Fixed O&M	444,230	224,359	453,205
Land Lease	199,386	209,880	220,374
FIRST YEAR O&M	$ 976,241	$ 750,153	$ 966,464

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)	Future
Resource (mph, avg.)	14.65	Extent (# of units)	6
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	30,603	27,821	25,039
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	27,941	24,010	20,357
CAPITAL COSTS			
Process Capital			
Turbines & Towers	6,885,000	7,650,000	8,797,500
Foundations	603,128	615,437	627,746
Assembly & Checkout	235,200	240,000	244,800
Electrical Infrastructure	728,627	743,497	758,367
Sub-Station	490,000	500,000	510,000
Overseas Shipping	294,000	300,000	306,000
Legal Fees & Permitting	298,175	372,718	465,898
General Facilities			
Roads & Grading	89,303	91,125	92,948
Control System	35,280	36,000	36,720
Control Buildings	21,168	21,600	22,032
Central Building	80,640	89,600	112,000
Engineering & Overhead	667,389	746,198	819,722
Project Contingency	834,233	912,494	1,023,498
Initial Costs	574,996	620,843	714,267
SUB-TOTAL	$11,837,138	$12,939,512	$14,531,497
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	49,289	47,060	43,890
Fixed O&M	80,769	40,793	82,401
Land Lease	12,084	12,720	13,356
FIRST YEAR O&M	$ 142,142	$ 100,572	$ 139,647

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)	Future
Resource (mph, avg.)	14.65	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	102,010	92,737	83,463
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	85,383	72,984	61,513
CAPITAL COSTS			
Process Capital			
Turbines & Towers	22,950,000	25,500,000	29,325,000
Foundations	2,010,427	2,051,456	2,092,485
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,428,756	2,478,322	2,527,888
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	345,404	431,755	539,694
General Facilities			
Roads & Grading	284,939	290,754	296,569
Control System	117,600	120,000	122,400
Control Buildings	70,560	72,000	73,440
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,167,801	2,403,372	2,649,575
Project Contingency	2,695,210	2,938,981	3,288,404
Initial Costs	1,892,978	2,102,034	2,348,312
SUB-TOTAL	$38,278,315	$41,778,274	$46,741,768
TRANSMISSION			
Cost of Upgrade	2,940,000	3,000,000	3,060,000
ANNUAL EXPENSES			
Variable O&M	150,616	143,049	132,622
Fixed O&M	269,231	135,975	274,670
Land Lease	40,280	42,400	44,520
FIRST YEAR O&M	$ 460,127	$ 321,424	$ 451,811

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)	Future
Resource (mph, avg.)	17.53	Extent (# of units)	20
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	127,074	115,522	103,970
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	106,362	90,917	76,626
CAPITAL COSTS			
Process Capital			
Turbines & Towers	22,950,000	25,500,000	29,325,000
Foundations	2,010,427	2,051,456	2,092,485
Assembly & Checkout	784,000	800,000	816,000
Electrical Infrastructure	2,752,590	2,808,765	2,864,940
Sub-Station	1,470,000	1,500,000	1,530,000
Overseas Shipping	980,000	1,000,000	1,020,000
Legal Fees & Permitting	346,141	432,676	540,846
General Facilities			
Roads & Grading	322,203	328,779	335,354
Control System	117,600	120,000	122,400
Control Buildings	70,560	72,000	73,440
Central Building	80,640	89,600	112,000
Engineering & Overhead	2,190,521	2,429,229	2,673,249
Project Contingency	2,725,975	2,970,600	3,320,457
Initial Costs	1,929,606	2,097,408	2,386,258
SUB-TOTAL	$38,730,263	$42,200,514	$47,212,430
TRANSMISSION			
Cost of Upgrade	882,000	900,000	918,000
ANNUAL EXPENSES			
Variable O&M	187,623	178,197	165,207
Fixed O&M	269,231	135,975	274,670
Land Lease	120,840	127,200	133,560
FIRST YEAR O&M	$ 577,693	$ 441,372	$ 573,436

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)	Future
Resource (mph, avg.)	17.53	Extent (# of units)	33
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	209,673	190,612	171,551
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	175,497	150,012	126,434
CAPITAL COSTS			
Process Capital			
Turbines & Towers	37,110,150	41,233,500	47,418,525
Foundations	3,317,204	3,384,902	3,452,600
Assembly & Checkout	1,293,600	1,320,000	1,346,400
Electrical Infrastructure	4,541,773	4,634,462	4,727,151
Sub-Station	2,450,000	2,500,000	2,550,000
Overseas Shipping	1,617,000	1,650,000	1,683,000
Legal Fees & Permitting	388,936	486,170	607,713
General Facilities			
Roads & Grading	528,087	538,864	549,641
Control System	194,040	198,000	201,960
Control Buildings	116,424	118,800	121,176
Central Building	80,640	89,600	112,000
Engineering & Overhead	3,550,306	3,930,801	4,324,977
Project Contingency	4,415,053	4,806,808	5,367,612
Initial Costs	3,126,563	3,406,827	3,862,872
SUB-TOTAL	$62,729,777	$68,298,735	$76,325,628
TRANSMISSION			
Cost of Upgrade	1,960,000	2,000,000	2,040,000
ANNUAL EXPENSES			
Variable O&M	309,577	294,024	272,591
Fixed O&M	444,230	224,359	453,205
Land Lease	199,386	209,880	220,374
FIRST YEAR O&M	$ 953,194	$ 728,263	$ 946,170

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)	Future
Resource (mph, avg.)	17.53	Extent (# of units)	53
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	336,747	306,134	275,521
Expected Losses (%)	16%	21%	26%
Net Energy (MWh/yr)	281,859	240,929	203,060
CAPITAL COSTS			
Process Capital			
Turbines & Towers	59,601,150	66,223,500	76,157,025
Foundations	5,327,631	5,436,358	5,545,086
Assembly & Checkout	2,077,600	2,120,000	2,162,400
Electrical Infrastructure	7,294,363	7,443,227	7,592,092
Sub-Station	3,920,000	4,000,000	4,080,000
Overseas Shipping	2,597,000	2,650,000	2,703,000
Legal Fees & Permitting	456,267	570,334	712,917
General Facilities			
Roads & Grading	844,831	862,073	879,314
Control System	311,640	318,000	324,360
Control Buildings	186,984	190,800	194,616
Central Building	80,640	89,600	112,000
Engineering & Overhead	5,689,181	6,293,272	6,926,676
Project Contingency	7,070,983	7,695,773	8,591,159
Initial Costs	5,016,741	5,581,662	6,197,009
SUB-TOTAL	$100,475,011	$109,474,599	$122,177,654
TRANSMISSION			
Cost of Upgrade	8,820,000	9,000,000	9,180,000
ANNUAL EXPENSES			
Variable O&M	497,200	472,221	437,798
Fixed O&M	713,461	360,334	727,874
Land Lease	320,226	337,080	353,934
FIRST YEAR O&M	$ 1,530,887	$ 1,169,635	$ 1,519,606

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)	Future
Resource (mph, avg.)	16.74	Extent (# of units)	2
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	12,085	10,986	9,887
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	11,034	9,481	8,039
CAPITAL COSTS			
Process Capital			
Turbines & Towers	2,409,750	2,677,500	3,079,125
Foundations	182,766	186,496	190,226
Assembly & Checkout	78,400	80,000	81,600
Electrical Infrastructure	323,834	330,443	337,052
Sub-Station	147,000	150,000	153,000
Overseas Shipping	98,000	100,000	102,000
Legal Fees & Permitting	284,789	355,986	444,982
General Facilities			
Roads & Grading	38,065	38,841	39,618
Control System	11,760	12,000	12,240
Control Buildings	7,056	7,200	7,344
Central Building	10,710	11,900	14,875
Engineering & Overhead	246,718	276,526	307,159
Project Contingency	307,108	338,151	381,538
Initial Costs	204,934	221,987	255,510
SUB-TOTAL	$ 4,350,889	$ 4,787,031	$ 5,406,269
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	19,463	18,583	17,331
Fixed O&M	26,923	13,598	27,467
Land Lease	4,028	4,240	4,452
FIRST YEAR O&M	$ 50,414	$ 36,421	$ 49,250

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)	Future
Resource (mph, avg.)	16.74	Extent (# of units)	10
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	60,423	54,930	49,437
Expected Losses (%)	13%	18%	23%
Net Energy (MWh/yr)	52,736	45,195	38,204
CAPITAL COSTS			
Process Capital			
Turbines & Towers	11,475,000	12,750,000	14,662,500
Foundations	913,830	932,480	951,130
Assembly & Checkout	392,000	400,000	408,000
Electrical Infrastructure	1,619,170	1,652,215	1,685,259
Sub-Station	735,000	750,000	765,000
Overseas Shipping	490,000	500,000	510,000
Legal Fees & Permitting	312,284	390,356	487,944
General Facilities			
Roads & Grading	168,489	171,927	175,366
Control System	58,800	60,000	61,200
Control Buildings	35,280	36,000	36,720
Central Building	80,640	89,600	112,000
Engineering & Overhead	1,115,610	1,241,280	1,362,888
Project Contingency	1,391,688	1,517,909	1,697,441
Initial Costs	961,305	1,066,594	1,190,718
SUB-TOTAL	$19,749,098	$21,558,361	$24,106,166
TRANSMISSION			
Cost of Upgrade	1,470,000	1,500,000	1,530,000
ANNUAL EXPENSES			
Variable O&M	93,027	88,583	82,368
Fixed O&M	134,615	67,988	137,335
Land Lease	20,140	21,200	22,260
FIRST YEAR O&M	$ 247,782	$ 177,771	$ 241,963

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)	Future
Resource (mph, avg.)	17.08	Extent (# of units)	6
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	34,667	31,515	28,364
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	31,651	27,198	23,060
CAPITAL COSTS			
Process Capital			
Turbines & Towers	6,885,000	7,650,000	8,797,500
Foundations	603,128	615,437	627,746
Assembly & Checkout	235,200	240,000	244,800
Electrical Infrastructure	971,502	991,329	1,011,155
Sub-Station	490,000	500,000	510,000
Overseas Shipping	294,000	300,000	306,000
Legal Fees & Permitting	298,727	373,409	466,761
General Facilities			
Roads & Grading	117,251	119,644	122,036
Control System	35,280	36,000	36,720
Control Buildings	21,168	21,600	22,032
Central Building	80,640	89,600	112,000
Engineering & Overhead	684,429	765,591	837,477
Project Contingency	857,306	936,209	1,047,538
Initial Costs	588,101	634,306	728,057
SUB-TOTAL	$12,161,733	$13,273,124	$14,869,823
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	55,833	53,309	49,718
Fixed O&M	80,769	40,793	82,401
Land Lease	36,252	38,160	40,068
FIRST YEAR O&M	$ 172,854	$ 132,261	$ 172,187

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)	Future
Resource (mph, avg.)	15.8	Extent (# of units)	3
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	**NOMINAL**	**CONSERVATIVE**
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	16,037	14,579	13,121
Expected Losses (%)	9%	14%	19%
Net Energy (MWh/yr)	14,642	12,582	10,668
CAPITAL COSTS			
Process Capital			
Turbines & Towers	3,614,625	4,016,250	4,618,688
Foundations	274,149	279,744	285,339
Assembly & Checkout	117,600	120,000	122,400
Electrical Infrastructure	364,313	371,748	379,183
Sub-Station	245,000	250,000	255,000
Overseas Shipping	147,000	150,000	153,000
Legal Fees & Permitting	288,203	360,253	450,317
General Facilities			
Roads & Grading	42,140	43,000	43,860
Control System	17,640	18,000	18,360
Control Buildings	10,584	10,800	11,016
Central Building	37,620	41,800	52,250
Engineering & Overhead	353,562	396,312	438,475
Project Contingency	440,995	484,633	546,231
Initial Costs	301,972	326,899	376,442
SUB-TOTAL	$ 6,255,404	$ 6,869,439	$ 7,750,561
TRANSMISSION			
Cost of Upgrade			
ANNUAL EXPENSES			
Variable O&M	25,828	24,661	22,999
Fixed O&M	40,385	20,396	41,200
Land Lease	6,042	6,360	6,678
FIRST YEAR O&M	$ 72,255	$ 51,417	$ 70,878

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
Resource (kWh/m²)	2,068	Extent (PV module area, m²)	48,400
Project Life (years)	30	Construction Time (years)	1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
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	$14,580,000	$16,200,000	$17,010,000
Array Structure & Foundations	$2,865,347	$3,016,155	$3,166,963
Power Condtioning Units	$966,875	$1,487,500	$1,561,875
Electrical & SCADA	$2,125,717	$2,147,189	$2,168,661
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$180,983	$190,508	$200,034
Legal Fees & Permitting	$578,027	$722,534	$903,167
General Facilities			
Roads and Grading	$337,872	$375,414	$412,955
Buildings and Fencing	$125,727	$139,697	$153,666
Engineering & Overhead	$1,924,484	$1,924,484	$1,924,484
Project Contingency	$2,252,130	$2,252,130	$2,252,130
Initial Costs	$365,630	$365,630	$365,630
SUB-TOTAL	**$26,580,347**	**$29,113,403**	**$30,426,336**
TRANSMISSION			
Cost of Upgrade	**$950,000**	**$1,000,000**	**$1,050,000**
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	Oahu	Location:	Pearl Harbor	Project Code:	
					(leave blank)

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

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	12,357	10,751	9,679
Expected Losses (%)	0.95%	1.00%	1.03%
Net Energy (MWh/yr)	**12,240**	**10,643**	**9,579**
CAPITAL COSTS			
Process Capital			
PV Modules	$10,206,000	$11,340,000	$11,907,000
Array Structure & Foundations	$2,063,050	$2,171,632	$2,280,213
Power Condtioning Units	$435,094	$669,375	$702,844
Electrical & SCADA	$1,676,128	$1,693,058	$1,709,989
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$162,885	$171,458	$180,030
Legal Fees & Permitting	$564,035	$705,044	$881,305
General Facilities			
Roads and Grading	$270,298	$300,331	$330,364
Buildings and Fencing	$118,069	$131,188	$144,306
Engineering & Overhead	$1,295,247	$1,295,247	$1,295,247
Project Contingency	$1,595,407	$1,595,407	$1,595,407
Initial Costs	$259,945	$259,945	$259,945
SUB-TOTAL	**$18,923,713**	**$20,624,848**	**$21,593,423**
TRANSMISSION			
Cost of Upgrade	**$950,000**	**$1,000,000**	**$1,050,000**
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)			current
Resource (kWh/m²)	2,358	Extent (PV module area, m²)			48,400
Project Life (years)	30	Construction Time (years)			1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
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	$14,580,000	$16,200,000	$17,010,000
Array Structure & Foundations	$2,865,347	$3,016,155	$3,166,963
Power Condtioning Units	$966,875	$1,487,500	$1,561,875
Electrical & SCADA	$2,125,717	$2,147,189	$2,168,661
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$180,983	$190,508	$200,034
Legal Fees & Permitting	$578,027	$722,534	$903,167
General Facilities			
Roads and Grading	$337,872	$375,414	$412,955
Buildings and Fencing	$125,727	$139,697	$153,666
Engineering & Overhead	$1,924,484	$1,924,484	$1,924,484
Project Contingency	$2,252,130	$2,252,130	$2,252,130
Initial Costs	$364,924	$364,924	$364,924
SUB-TOTAL	**$26,579,641**	**$29,112,697**	**$30,425,630**
TRANSMISSION			
Cost of Upgrade	**$352,800**	**$360,000**	**$367,200**
ANNUAL EXPENSES			
Variable O&M	$14,539	$16,154	$17,770
Fixed O&M	$23,156	$24,375	$25,594
Land Lease	$8,049	$8,472	$8,896
FIRST YEAR O&M	**$45,744**	**$49,002**	**$52,259**

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
Resource (kWh/m²)	2,358	Extent (PV module area, m²)			38,320
Project Life (years)	30	Construction Time (years)			1

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	12,357	10,751	9,679
Expected Losses (%)	0.95%	1.00%	1.03%
Net Energy (MWh/yr)	**12,240**	**10,643**	**9,579**
CAPITAL COSTS			
Process Capital			
PV Modules	$10,206,000	$11,340,000	$11,907,000
Array Structure & Foundations	$2,063,050	$2,171,632	$2,280,213
Power Condtioning Units	$435,094	$669,375	$702,844
Electrical & SCADA	$1,676,128	$1,693,058	$1,709,989
Substation	$277,555	$292,163	$306,771
Overseas Shipping	$162,885	$171,458	$180,030
Legal Fees & Permitting	$564,035	$705,044	$881,305
General Facilities			
Roads and Grading	$270,298	$300,331	$330,364
Buildings and Fencing	$118,069	$131,188	$144,306
Engineering & Overhead	$1,295,247	$1,295,247	$1,295,247
Project Contingency	$1,595,407	$1,595,407	$1,595,407
Initial Costs	$259,386	$259,386	$259,386
SUB-TOTAL	**$18,923,153**	**$20,624,289**	**$21,592,863**
TRANSMISSION			
Cost of Upgrade	**$352,800**	**$360,000**	**$367,200**
ANNUAL EXPENSES			
Variable O&M	$13,616	$15,129	$16,642
Fixed O&M	$21,943	$23,098	$24,253
Land Lease	$6,374	$6,709	$7,044
FIRST YEAR O&M	**$41,933**	**$44,936**	**$47,940**

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)	current
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	$244,405	$256,728	$269,565
Penstock	$7,048,307	$7,403,684	$7,773,868
Tailrace	$332,978	$349,767	$367,255
Diversion Structure	$1,773,418	$1,862,834	$1,955,976
Powerhouse	$1,224,664	$1,286,412	$1,350,732
Turbine	$2,268,007	$2,382,360	$2,501,478
Generaator	$3,041,197	$3,194,535	$3,354,262
Switchgear	$636,616	$668,714	$702,150
Equipment Installation	$209,426	$219,985	$230,984
Interconnection	$1,020,498	$1,071,952	$1,125,549
Legal Fees & Permitting	$637,346	$669,481	$702,955
Environmental Monitoring	$435,272	$457,219	$480,080
General Capital Facilities			
Access Road	$629,018	$660,733	$693,770
Station Service	$209,426	$219,985	$230,984
Telecommunications	$55,623	$58,427	$61,349
Engineering Services			
Engineering	$1,581,296	$1,661,025	$1,744,077
Construction Management	$1,581,296	$1,661,025	$1,744,077
Post Construction Environmental	$98,499	$103,465	$108,638
Project Contingency	$2,302,729	$2,418,833	$2,539,775
SUB-TOTAL	**$25,330,022**	**$26,607,166**	**$27,937,524**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$82,855	$87,033	$91,384
Fixed O&M	$79,260	$83,256	$87,419
Rep. Spare Parts (sinking fund)	$25,330	$26,608	$27,938
Land Lease	$24,335	$25,562	$26,840
Federal Fees	$10,545	$11,077	$11,631
FIRST YEAR O&M	**$222,325**	**$233,535**	**$245,212**

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
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	$244,405	$256,728	$269,565
Penstock	$7,048,307	$7,403,684	$7,773,868
Tailrace	$332,978	$349,767	$367,255
Diversion Structure	$1,773,418	$1,862,834	$1,955,976
Powerhouse	$1,224,664	$1,286,412	$1,350,732
Turbine	$2,268,007	$2,382,360	$2,501,478
Generaator	$3,041,197	$3,194,535	$3,354,262
Switchgear	$636,616	$668,714	$702,150
Equipment Installation	$209,426	$219,985	$230,984
Interconnection	$1,020,498	$1,071,952	$1,125,549
Legal Fees & Permitting	$637,346	$669,481	$702,955
Environmental Monitoring	$435,272	$457,219	$480,080
General Capital Facilities			
Access Road	$629,018	$660,733	$693,770
Station Service	$209,426	$219,985	$230,984
Telecommunications	$55,623	$58,427	$61,349
Engineering Services			
Engineering	$1,581,296	$1,661,025	$1,744,077
Construction Management	$1,581,296	$1,661,025	$1,744,077
Post Construction Environmental	$98,499	$103,465	$108,638
Project Contingency	$2,302,729	$2,418,833	$2,539,775
SUB-TOTAL	**$25,330,022**	**$26,607,166**	**$27,937,524**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$82,855	$87,033	$91,384
Fixed O&M	$59,445	$62,442	$65,564
Rep. Spare Parts (sinking fund)	$25,330	$26,608	$27,938
Land Lease	$24,335	$25,562	$26,840
Federal Fees	$10,545	$11,077	$11,631
FIRST YEAR O&M	**$202,510**	**$212,721**	**$223,357**

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Hydroelectric

Island	Kauai	Location:	Wailua River	Project Code:	
Capacity (MW)	6.6	Stage (current/future)			current
Resource (cfs, max)	365	Extent (feet of head)			262
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	$212,526	$223,241	$234,403
Penstock	$3,504,243	$3,680,927	$3,864,973
Tailrace	$103,829	$109,065	$114,518
Diversion Structure	$848,156	$890,921	$935,467
Powerhouse	$488,091	$512,701	$538,336
Turbine	$903,916	$949,492	$996,966
Generaator	$1,355,877	$1,424,240	$1,495,452
Switchgear	$416,588	$437,592	$459,472
Equipment Installation	$105,452	$110,769	$116,307
Interconnection	$321,801	$338,026	$354,927
Legal Fees & Permitting	$163,531	$171,777	$180,365
Environmental Monitoring	$73,005	$76,686	$80,520
General Capital Facilities			
Access Road	$77,872	$81,798	$85,888
Sable Storm Ditch	$97,340	$102,248	$107,360
Relocate USGS Gage	$25,957	$27,266	$28,629
Station Service	$97,340	$102,248	$107,360
Telecommunications	$25,957	$27,266	$28,629
Engineering Services			
Engineering	$706,433	$742,051	$779,154
Construction Management	$706,433	$742,051	$779,154
Post Construction Environmental	$73,005	$76,686	$80,520
Project Contingency	$1,030,735	$1,082,705	$1,136,840
SUB-TOTAL	**$11,338,087**	**$11,909,756**	**$12,505,244**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$94,154	$98,901	$103,846
Fixed O&M	$80,233	$84,278	$88,492
Rep. Spare Parts (sinking fund)	$11,349	$11,921	$12,517
Land Lease	$14,485	$15,215	$15,976
Federal Fees	$7,243	$7,608	$7,989
FIRST YEAR O&M	**$207,464**	**$217,924**	**$228,820**

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Hydroelectric

Island	Kauai	Location:	Wailua River	Project Code:	

Capacity (MW)	6.6	Stage (current/future)	future
Resource (cfs, max)	365	Extent (feet of head)	262
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	$212,526	$223,241	$234,403
Penstock	$3,504,243	$3,680,927	$3,864,973
Tailrace	$103,829	$109,065	$114,518
Diversion Structure	$848,156	$890,921	$935,467
Powerhouse	$488,091	$512,701	$538,336
Turbine	$903,916	$949,492	$996,966
Generaator	$1,355,877	$1,424,240	$1,495,452
Switchgear	$416,588	$437,592	$459,472
Equipment Installation	$105,452	$110,769	$116,307
Interconnection	$321,801	$338,026	$354,927
Legal Fees & Permitting	$163,531	$171,777	$180,365
Environmental Monitoring	$73,005	$76,686	$80,520
General Capital Facilities			
Access Road	$77,872	$81,798	$85,888
Sable Storm Ditch	$97,340	$102,248	$107,360
Relocate USGS Gage	$25,957	$27,266	$28,629
Station Service	$97,340	$102,248	$107,360
Telecommunications	$25,957	$27,266	$28,629
Engineering Services			
Engineering	$706,433	$742,051	$779,154
Construction Management	$706,433	$742,051	$779,154
Post Construction Environmental	$73,005	$76,686	$80,520
Project Contingency	$1,030,735	$1,082,705	$1,136,840
SUB-TOTAL	**$11,338,087**	**$11,909,756**	**$12,505,244**
TRANSMISSION			
Cost of Upgrade	**$1,000,000**	**$1,000,000**	**$1,000,000**
ANNUAL EXPENSES			
Variable O&M	$94,154	$98,901	$103,846
Fixed O&M	$60,175	$63,209	$66,369
Rep. Spare Parts (sinking fund)	$11,349	$11,921	$12,517
Land Lease	$14,485	$15,215	$15,976
Federal Fees	$7,243	$7,608	$7,989
FIRST YEAR O&M	**$187,405**	**$196,854**	**$206,697**

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Geothermal

Island:	Hawaii	Location:	Kilauea	Project Code:	
		Ownership:	Puna Geothermal Venture		
Capacity (MW)	8			Stage (current/future):	Current
Resource	High enthalpy			Extent (# of units):	1 (Topping Unit)
Project Life (years)	30			Construction Time (years):	1
Geology Type	Rift Zone				

	OPTIMISTIC	NOMINAL	CONSERVATIVE
ENERGY PRODUCTION			
Gross Energy (MWh/yr)	56,250	52,500	45,000
Expected Losses (%)	4%	8%	14%
Net Energy (MWh/yr)	54,000	48,300	38,700
CAPITAL COSTS ($)			
Process Capital			
Exploration & Assessment	50,000	200,000	300,000
Production & Injection Wells	4,000,000	5,000,000	7,000,000
Gathering/Injection System	500,000	1,000,000	1,500,000
Power Plant	7,000,000	8,000,000	9,000,000
Substation Tie-In	50,000	100,000	150,000
Water Supply	0	0	0
Permitting, Legal, Environmental	50,000	100,000	150,000
General Facilities			
Roads & Site Work	50,000	100,000	150,000
Control and Office Buildings	50,000	100,000	150,000
Land Acquisition	0	0	0
Engineering & Overhead	800,000	1,000,000	1,200,000
Project Contingency	1,000,000	2,000,000	2,500,000
Initial Costs	0	0	0
TOTAL CAPITAL COSTS ($)	13,550,000	17,600,000	22,100,000
Capital Cost per kW (excluding transmission)	1,694	2,200	2,763
Capital Cost per kW (including transmission)	1,694	2,200	2,763
ANNUAL EXPENSES ($)			
Variable O&M	80,000	120,000	160,000
Fixed O&M	200,000	250,000	300,000
Land Lease	0	0	0
TOTAL FIRST YEAR O&M	280,000	370,000	460,000
O&M per KWh (mills)	5.2	7.7	11.9

HAWAII ENERGY STRATEGY
RENEWABLE ENERGY ASSESSMENT
TECHNOLOGY DATA SHEET

TECHNOLOGY: Geothermal

Island: Hawaii | Location: Kilauea | Project Code:
Ownership: Puna Geothermal Venture

Capacity (MW)	22	Stage (current/future):	Future (2005)
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)	200,000	193,000	170,000
Expected Losses (%)	4%	8%	14%
Net Energy (MWh/yr)	192,000	177,560	146,200
CAPITAL COSTS ($)			
Process Capital			
Exploration & Assessment	200,000	500,000	800,000
Production & Injection Wells	9,000,000	12,000,000	15,000,000
Gathering/Injection System	2,000,000	2,500,000	3,000,000
Power Plant	25,000,000	30,000,000	35,000,000
Substation Tie-In	200,000	300,000	400,000
Water Supply	500,000	1,000,000	1,300,000
Permitting, Legal, Environmental	500,000	600,000	700,000
General Facilities			
Roads & Site Work	500,000	800,000	1,000,000
Control and Office Buildings	400,000	500,000	600,000
Land Acquisition	150,000	200,000	250,000
Engineering & Overhead	4,000,000	5,000,000	6,000,000
Project Contingency	5,000,000	6,000,000	7,000,000
Initial Costs	1,000,000	2,000,000	3,000,000
TOTAL CAPITAL COSTS ($)	48,450,000	61,400,000	74,050,000
Capital Cost per kW (excluding transmission)	2,202	2,791	3,366
Capital Cost per kW (including transmission)	2,222	2,816	3,396
ANNUAL EXPENSES ($)			
Variable O&M	250,000	300,000	400,000
Fixed O&M	600,000	750,000	900,000
Land Lease	300,000	500,000	700,000
TOTAL FIRST YEAR O&M	1,150,000	1,550,000	2,000,000
O&M per KWh (mills)	6.0	8.7	13.7

SECTION 5.

DESCRIPTIONS OF SMALL-SCALE RENEWABLE ENERGY APPLICATIONS

Prepared by
National Renewable Energy Laboratory
October 16, 2000

Photovoltaic Systems in Hawaii

Photovoltaic (or PV) cells are devices that use semiconductor materials to convert sunlight directly into electricity. The electric current can either be used immediately, or it may be stored in a battery for later use. PV cells are modular, and can be combined together to create any amount of power necessary. As such, this technology is used in applications ranging from wristwatches to utility-scale power plants.

The amount of power generated by a flat-plate PV array at a particular site depends on how much of the sun's energy reaches it from all directions—the "global solar radiation." PV arrays are usually tilted at an
angle equal to the site's latitude, which allows the array to capture the most sunlight over the course of a year. So, the important resource data for PV arrays is the global solar radiation at an angle equal to the latitude.

Hawaii has an excellent solar resource. Analysis performed for the National Renewable Energy Laboratory indicates that a PV system rated at one (1) kilowatt ac would produce between 1,800 and 2,000 kilowatt-hours per year in Hawaii.

Opportunities: The main advantages of PV energy systems are their modularity, portability, high reliability, and low environmental impact. These systems have no or few moving parts, which results in low operating and maintenance costs.

Currently, the largest market for PV is the off-grid market, which takes advantage of PV's ability to be a complete stand-alone electrical system. Telecommunications and transportation construction signage are the two largest segments of the off-grid market. Most of the off-grid market stems from applications that are in remote locations and/or cannot access the utility grid. Examples are water pumping and highway lighting.

The emerging grid-connected PV market provides a distributed generation resource to the electric grid. The PV system may tie to the grid at the substation to relieve transmission line load. Or it may tie at the industrial, commercial, or residential customer site to support both the transmission and distribution systems for load and losses. A major portion of U.S. utilities, through recent cooperative research funded by the National Renewable Energy Laboratory, has identified the capacity contribution of PV to the grid. Of note, solar-related loads such as air conditioning often cause capacity constraints in generation, transmission, and distribution. At these times, distributed PV can provide added benefits to the power grid. The photo shows the Hawaiian Island Humpback Whale National Marine Sanctuary, the first PV grid-connected system on the Island of Maui.

Economics: The same values that drive the PV system market also set the wide range of PV costs. The high capital costs of $5 to $12 per watt is offset by low operating costs—that is, no fuel. The 20-year life-cycle cost ranged from 20 cents to 50 cents per kilowatt-hour.

A remote home installation that requires batteries, a generator, or both may need 2 to 5 kilowatts of power at $12 per watt, or a high cost of $60,000. However, the cost of a rural distribution line now averages $60,000 per mile. With the additional advantage of lower land costs in remote areas, PV shapes up as the best value.

At the other end of the cost range, the most recent bid at the Sacramento Municipal Utility District (SMUD) was $4.40 per watt for installed systems. Several years ago, the community of Sacramento decided to meet electricity demand requirements with efficiency and renewable energy. The continued decline in SMUD's purchase costs reflects the buying advantage of large-volume annual purchases.

According to a June 1999 study co-authored by scientists at the National Renewable Energy Laboratory, Hawaii has one of the best economic markets in the country for residential photovoltaics. The breakeven cost for a turnkey system is estimated at $7.91/watt. Despite the fact that Hawaii incurs higher shipping costs, systems today could be economic. In addition, if Hawaii decided to install a large quantity of PV systems – in other words, to buy in bulk as Sacramento has done – the use of photovoltaics systems could mean significant savings for consumers.

An additional benefit is that the costs of solar systems are predetermined. The cost of electricity does not change with fuel costs as is standard with current Hawaiian electricity. And since PV systems supply power that closely matches air-conditioning loads and daytime power peaks, the use of PV as distributed power could be used to strengthen the electricity grid.

Mauna Lani Bay Hotel: One oft-cited example of the use of PV in Hawaii is the Mauna Lani Bay Hotel on the Big Island in Hawaii. Photovoltaic roofing tiles cover 10,000 square feet and generate 75 net kilowatts of electricity for the hotel. This sprawling hotel had acres of roof space, making it the perfect host for a photovoltaic system. Working with PowerLight Corporation, the hotel's owners installed a PowerGuard® system of insulating PV roofing tiles that covers 10,000 square feet and generates 75 net kilowatts of electricity. A combination of the insulation and the electricity generated by the PV system produced an internal rate of return over 20% for the hotel. The Mauna Lani is an example of building-integrated PV (BIPV) at its finest. BIPV applications, which can be strikingly beautiful, are common in European countries, where the cost of electricity is higher than much of the United States.

Economics of Small Wind Turbines in Hawaii

Small wind turbines are typically used in remote or rural areas of the world including; a village in Chile, a cabin dweller in the US, a farmer who wants to water his crops or stock, or homeowners who want to reduce their utility bills.

Most small wind turbines are used to produce electricity but some produce mechanical work or pump water. Water pumping windmills have been in use for hundreds of years and are still sold today for water pumping needs. Many farms throughout the Midwest in the 1920s and 1930s generated electricity with wind turbines, which powered the lights, appliances, and electric motors.

Small wind turbines, which produce electricity, can either be used in connection with the utility grid or in a stand-alone application not connected to the grid. Small wind turbines that are connected to the utility grid can reduce energy consumption by displacing the electricity purchased from the utility. Turbines used in a stand-alone application can become part of a hybrid power system, a combination of wind turbines and other power sources, such as: photovoltaics, micro-hydro and/or diesel generators. When combined with energy storage, hybrid power systems are often more economical than extending the utility grid to a house.

The economics of a wind turbine are affected primarily by three factors. The first two affect all installations; these are the wind resource at the site of installation and the capital cost of the system. The third factor, which only affects systems connected to the electricity grid, involved the value placed on excess electricity from the system.

For wind resource, the power produced from a wind turbine is extremely dependent on the speed of the wind at the site. For example, if the wind speed doubles, the power output will quadruple. The variability of the wind is also a factor. For an island or coastal environment, there will be wind throughout the year independent of season. For small wind turbines the wind resource is extremely important in increasing the economic benefit and care should be taken to install a turbine at the best site possible.

In Hawaii, there is a vast wind resource ranging from an annual average of 3 m/s up to 9 m/s at a 30m height. (The wind increases as a function of height above the earth's terrain.) Typical small wind turbine tower heights can range from 24 feet on up to 120 feet but are generally between 60 and 80 feet. Since the upper wind speed in Hawaii is 9 m/s at 98.4 feet (30m) we reduced the wind speed used in our analyses to account for lower tower heights. Analysis was run for wind speeds of 3 m/s, 5 m/s and 7 m/s.

There are many things which will influence small wind turbine economics such as: turbine costs, balance of systems costs (i.e. inverters, batteries, cabling, foundation, etc.), wind speed, value of electricity, economic incentives (i.e. rebate programs, tax incentives), maintenance and repair costs, tower height, and others. Although small wind turbines involve significant initial investment, they can be competitive with conventional energy sources compared on a life cycle cost basis. Several states currently offer rebate programs or tax incentives up to 50-60% of the system's cost.

For Hawaii we did an analytical study of two (2) turbine models, the Bergey XL.1 (currently selling for approximately $3,000) and the Jacob's 20 kW turbine (currently selling for approximately $34,000). We assumed a 20 year turbine life, a discount rate of 6%, a retail rate for electricity of $.15/kWh, and an avoided cost electricity rate of $.03/kWh. A homeowner's electricity load was assumed at 7300 kWh annually. In addition, we ran scenarios both with and without tax credits. In this we assumed the current Hawaii tax credit of 20% with the full benefit taken in the first year of wind turbine use.

The third factor in the economic analysis is "net metering." Under current federal law, any excess energy produced by a wind turbine can be sold to the utility at the utility's "avoided cost." This is typically defined as the presumed cost that the utility would have incurred if it had produced the power. However, many states have added to this value by adopting "net metering " rules. This allows the owner of a system to use the excess electricity from a wind system to offset the customer's load at another point in time. In essence, it allows the electricity meter to run both forward and backward. The utility just bills based on the "net" kilowatt-hours used in each pay period. For this analysis, we ran scenarios with and without net metering provisions. If the system still produces more kilowatt-hours during the year than were used on-site, the excess electricity was then credited at avoided cost. Note, net metering does not affect the cost of energy, but does affect the life-cycle economics of a wind system.

Figure 1 shows the approximate range of small wind turbine economics in terms of Cost of Energy for two scenarios. The first scenario assumes <u>no</u> state policies such as a tax credit. This results in the higher Cost of Energy (CoE). The second scenario is for a 20% state tax benefit. As expected, the higher the wind speed (noted in meters per second [m/s]) the better the CoE. These scenarios were run with three system designs: a single 1 kW Bergey turbine; two Bergey turbines installed together; and a single 20 kW Jacob's turbine.

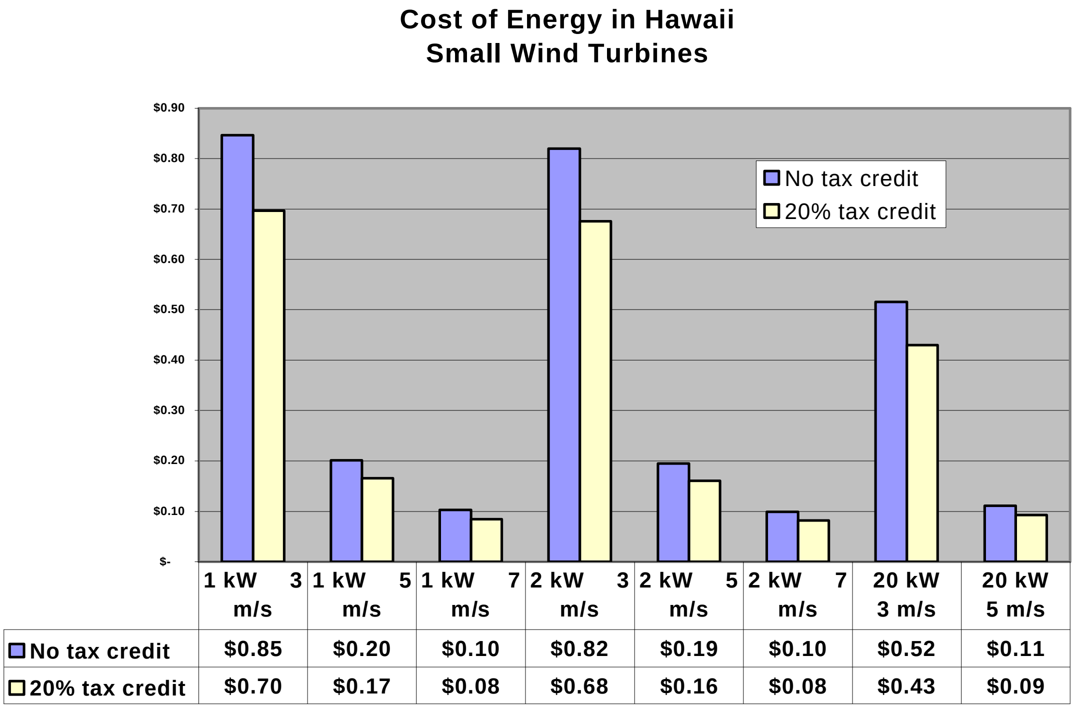


Figure 1 - Cost of Energy for Hawaii

Figure 2 shows the net annualized cost as a function of the different analyses for the two turbine models, four economic scenarios and 3 average annual wind speeds. In this chart, each of the above scenarios is separately run with and without net metering. The line shown indicates the breakeven point, which is determined by the cost of the electricity provided to the homeowner by the utility grid.

Note that this breakeven point assumes the homeowner is evaluating the turbine cost as the only reason for buying and installing a wind turbine. There are often other motivators for the homeowner including independence from the utility grid, a desire to use a renewable resource to minimize the environmental damage due to air pollution, or a desire to try wind technology. In addition, utilities may find that distributed resources can bolster the strength of the electricity grid.

The assumptions used in these analyses are the same as the assumptions used for the CoE analyses, including the annual electricity load of 7300 kWh. Again note that the state tax credit and higher average annual wind speed offer an economic incentive for the homeowner.
NOTE: The reason that the 20 kW turbine does not offer an attractive economic incentive is because this analysis was done from a homeowner's perspective. The 20 kW system provides far more electricity than the homeowner would use, and excess is sold to the utility at a very low rate – $0.03/kWh. However, these systems provide a low cost of energy, and could be very economical when analyzed from the utility perspective.

In fact, a turbine that meets and does not exceed the homeowner's electric load would be the economic optimum. A typical US homeowner uses up to 9000 kWh hours per year, which can often be matched to a 3-5 kW wind turbine. At present US manufacturers offer 1.5 kW turbines, a 3 kW turbine, and 10 kW turbines. There are subcontracts between two US manufacturers and NREL to develop two new turbines in the 5-10 kW size range.

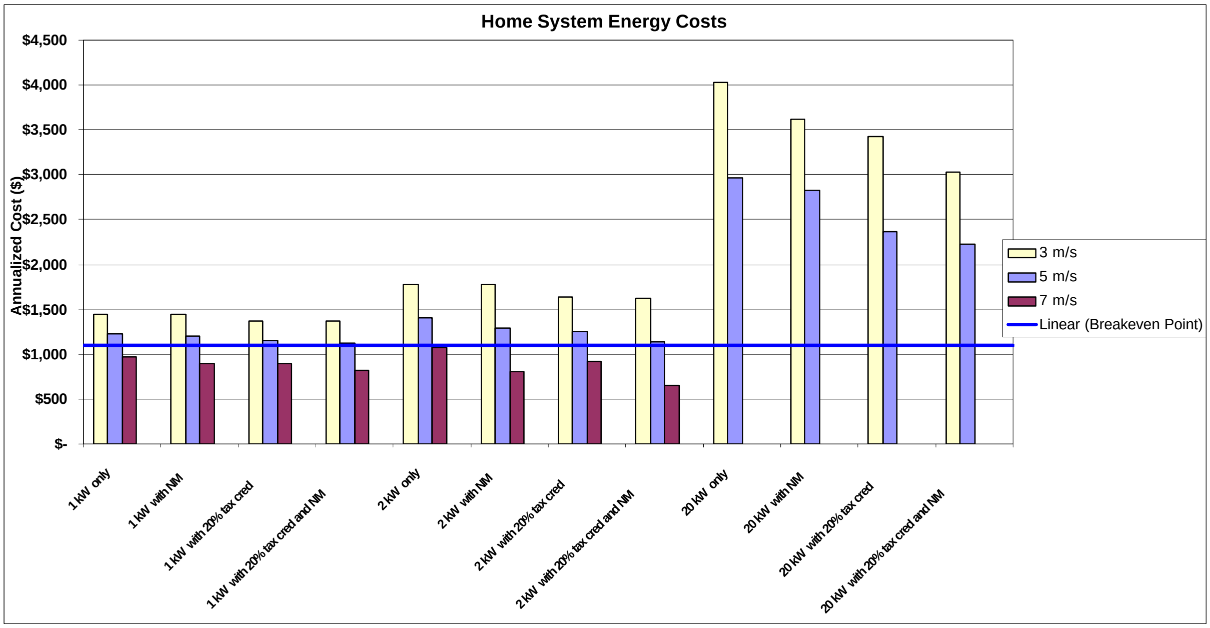


Figure 2 - Home Energy System Cost

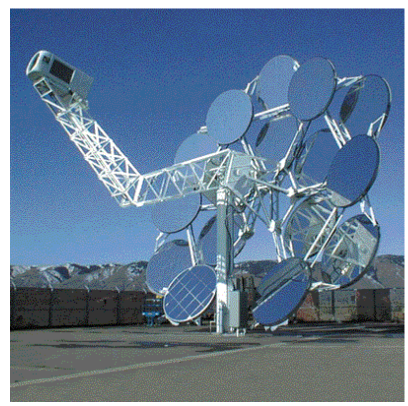
More information on small wind can be found at http://www.awea.org/ or http://www.nrel.gov/win

Solar Dish Systems in Hawaii

A dish/converter system is a stand-alone unit composed primarily of a collector, a receiver, and an engine or other means to make electricity from sunlight. The sun's energy is collected and concentrated by a dish-shaped surface onto a receiver that absorbs the energy and transfers it to an engine's working fluid or directly converts the energy to electricity. For the case of an engine, the engine converts the heat to mechanical power in a manner similar to conventional engines--that is, by compressing the working fluid when it is cold, heating the compressed working fluid, and then expanding it through a turbine or with a piston to produce work. The mechanical power is converted to electrical power by an electric generator or alternator. For the case of concentrating photovoltaic devices, the energy in sunlight is converted directly to electricity through the use of high efficiency silicon or multi-junction solar cells.

Dish systems use dual-axis collectors to track the sun. The ideal concentrator shape is parabolic, created either by a single reflective surface or multiple reflectors, or facets. Many options exist for receiver and engine type, including Stirling and Brayton engines and high concentration photovoltaic converters.

Dish power systems are not commercially deployed yet, although ongoing demonstrations indicate good potential. Individual dish/engine systems under development generate from 1 to 25 kilowatts of electricity. More capacity is possible by installing groups of dishes. Some systems can be combined with natural gas and the resulting hybrid provides continuous power generation. Because of their relatively small size and modular nature, these systems are ideal for distributed power generation.



This second-generation prototype system, rated at 25 kW, was installed in 1998.

Solar dish systems convert the energy from the sun into electricity at a very high efficiency. Using a mirror array formed into the shape of a dish, the solar dish focuses the sun's rays onto a receiver. The receiver transmits the energy to an engine or PV converter that generates electric power.

Because of the high concentration ratios achievable with parabolic dishes and the small size of the receiver, solar dishes are efficient at collecting solar energy at very high temperatures. Tests of prototype dish/Stirling systems at locations throughout the United States have demonstrated net solar-to-electric conversion efficiencies as high as 30%. This is significantly higher than any other solar technology.

Benefits: Solar dish/engine systems have environmental, operational, and potential economic advantages over more conventional power generation options because they:

- produce zero emissions when operating on solar energy;
- operate more quietly than diesel or gasoline engines;
- are easier to operate and maintain than conventional engines;
- start up and shut down automatically; and
- operate for long periods with minimal maintenance.

Because of their size and durability, solar dish/engine systems are well suited for non-traditional power generation. Individual units range in size from 1 to 25 kilowatts (kW). They can operate independently of power grids in remote sunny locations for uses such as pumping water and providing power to people living in isolated villages.

Dish/engine systems also can be linked together to provide utility-scale power to a transmission grid. Such systems could be located near consumers, substantially reducing the need for building or upgrading transmission capacity. Largely because of their high efficiency, the cost of these systems is expected to be lower than that of other solar systems for these applications.

Solar dish/engine systems are categorized as "solar concentrators" because they focus the sun's rays to produce heat and power. As such, they can only use the direct rays coming from the sun. Unlike "flat-plate" solar technologies, concentrators cannot make use of diffuse sunlight. As such, the usable solar resource for these technologies is more limited. In the U.S., the top resources for this technology are limited to the Southwest U.S. and some of the Hawaiian Islands.

Costs: The costs of solar dish engine systems are expected to decrease dramatically over the next couple decades. In fact, estimates published by the U.S. Department of Energy Concentrating Solar Program indicate that costs could drop by nearly 70% between 1998 and 2010.

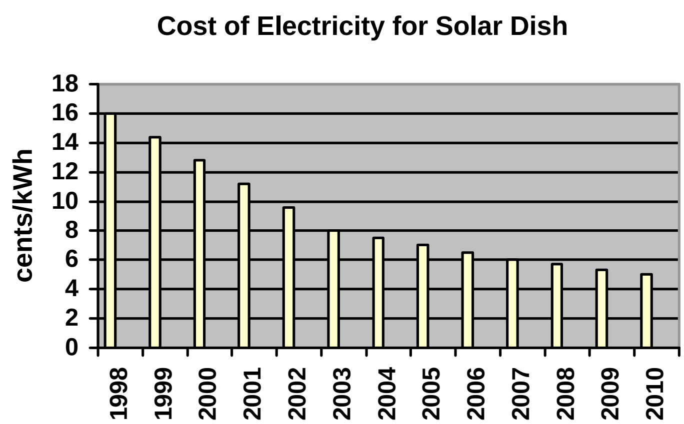


Figure 1: Cost of Electricity for Solar Dish/Engine System
Source: A Strategic Plan for Solar Thermal Electricity: A Bright Path to the Future, December 1996, and NREL technology manager, Nov 1997

The cost and efficiency of the technology – the focus of the federal research program, affect the economics of these systems. But the economics also depend on the level of solar resource and other credits such as tax incentives, net metering, and rebates. Figure 1 shows the projected cost decreases stemming from technology improvements. These estimates assume a good direct solar resource, but do not include the current Hawaii tax credit, or any other policy incentives. Several of the Hawaiian Islands have a resource suitable for this technology.

APPENDIX 2. RENEWABLE PORTFOLIO STANDARDS IN OTHER STATES

This appendix presents examples of specific economic benefits of renewable resources found by those States that have implemented Renewables Portfolio Standards. It is important to note again that these states enjoy the lower costs of fossil fuel prevalent on the Mainland through access to relatively inexpensive coal and natural gas. As a result, renewable energy may cost more than fossil fuel alternatives and is reflected in the relatively modest goals of most of the states. They expect renewable energy to cost more in the early years and methods of funding the difference are included in their plans. In addition, some of the states had little or no renewable energy in use prior to creating their RPS. The analysis for Hawaii described in the previous section showed that renewable energy would cost less than fossil generation on a statewide basis.

A. Arizona

The State of Arizona recently completed a study of the economic impacts of a RPS focused on solar energy, a Solar Portfolio Standard (SPS).[49] Under the Arizona SPS, the solar portfolio percentage (percent of total retail energy sold) increases annually from 0.4% in 2001 to 1% for the year 2005 and after. Analysis of a number of solar portfolio scenarios showed that the Solar Portfolio Standard will provide significant employment increases over a base case scenario, as well as increased income for the State. It was also determined that the SPS could help stimulate a solar manufacturing industry in Arizona.

Arizona's economic impact study, completed in 1997, was done at the request of the Arizona Solar Portfolio Standard Subcommittee for an independently derived analysis of the impact of suggested changes to the Arizona Solar Portfolio Standard (SPS).[50] Pacific Energy Group, under subcontract to the National Renewable Energy Laboratory (NREL), developed a computer spreadsheet tool to analyze costs, deployment schedule, and rate impacts of five different SPS options in effect at that time.[51] Depending on the SPS option selected, the Base Case results indicated that 250 to 330 MW of new solar capacity would be needed by the year 2010 at a total cost to Energy Service Providers (ESPs) of $450 to $750 million (1998$). This cost range results in a rate increase of about 0.6% to 1.0% or $0.0005/kWh to $0.0008/kWh.
The analysis also found significant economic benefits to the State of Arizona from the SPS. These benefits included some 600 new jobs created and $450 million quantified benefits for additional wages, salaries, state income taxes, and avoided environmental externalities. Table A2-1 below lists the economic benefits identified in this study.

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[49] Arizona Corporation Commission, *Assessing the Economic Impacts of a Solar Portfolio Standard in Arizona*, prepared by MRG & Associates, July 1999

[50] The rule in place at that time set the Arizona Portfolio Standard at one-half of one percent beginning in 1999 and one percent beginning in 2002.

[51] The spreadsheet tool is available for downloading at www.PacificEnergy.com

Table A2-1. Preliminary Estimate of Selected SPS Benefits to Arizona		
Parameter	**Result**	**Notes**
Jobs Created by 2010	600 jobs	From operating solar plants, 20 MW/yr. local manufacturing, and ancillary services. Indirect and induced effects are not included.
Wage, salary, and state income tax revenue (1998-2020)	$200 million	$400 million in nominal $. Does not include other direct, indirect, and induced effects normally considered in a full input-output model used in economic development analysis. These multipliers are considerable.
Global warming CO_2 emissions avoided by 2020	12 million tons, $120 million	At $13/ton this equates to $120 million in 1998$.
Acid rain SO_x emissions avoided by 2020	32 thousand tons, $85 million	At $2.03/lb this equates to $85 million in 1998$
Smog NO_x emissions avoided by 2020	38 thousand tons, $40 million	At $0.82/lb this equates to $40 million in 1998$.

A follow-up study conducted for the Salt River Project (SRP) in Arizona in 1998 examined potential solar electric business opportunities for SRP in light of a proposed renewable portfolio standard.[52] The business opportunities identified and evaluated included: investment in photovoltaic (PV) manufacturing (full ownership, debt and equity positions); sales of PV systems, green products, and fixed price electricity products; financing PV systems; selling O&M contracts; and selling performance guarantee contracts. Results of this study indicated that each of these areas has the potential to be a profitable business opportunity for SRP. In addition, some of the opportunities are businesses that could be readily extended to locations outside of SRP's service territory (manufacturing investment, financing, and selling performance guarantee contracts).

Arizona also evaluated the costs and ratepayer impacts of a broader Renewables Portfolio Standard in 1999. While economic benefits were not assessed in this second study, the study results indicated that implementation of a broader renewable portfolio standard resulted in slightly higher (+0.5%) electric bills.[53]

B. Minnesota

In Minnesota, proponents of the RPS submitted a report to the Minnesota Legislature in September 1999.[54] The RPS supporters cited an assessment of economic benefits for the region prepared by the Union of Concerned Scientists (UCS), which showed that the High Plains region could get over half of its electricity from renewables

[52] Hoff, Thomas, *An Analysis of the Solar Portfolio Standard and Solar Electric Investment Opportunities*. Study prepared for SRP and NREL, January 1998.
[53] Arizona Corporation Commission, "Evaluation of a Renewable Portfolio Standard in Arizona"
[54] Comments to Minnesota's Legislative Electric Energy Task Force, submitted September 30, 1999 by the Center for Energy and Environment, Institute for Local Self Reliance, Izaak Walton League of America, Clean Water Action Alliance, Minnesotans for an Energy Efficient Economy, and the Union of Concerned Scientists.

(wind and biomass) by 2020 under a 20% national RPS. The cost was estimated to be an additional $1.33 on a typical household's monthly electricity bill.

Since the level of development exceeded the 20% requirement, renewable developers in the region also would be able to sell excess credits to other states to help meet the proposed national requirement at the lowest cost. The income received from these credit sales would support the development of a renewable energy industry in Minnesota, providing jobs and income for state businesses, farmers, and rural economies, diversifying the state's energy mix, and capturing environmental benefits. The study also documented the environmental and health impacts from power plant pollution.

A coalition in Minnesota that promotes development of renewable resources, the Sustainable Energy for Economic Development (SEED) project, started a community-based renewable energy campaign in Minnesota in 1993. Four organizations, the Clean Water Fund, Minnesotans for an Energy-Efficient Economy, The Minnesota Project, and the Sustainable Resources Center, joined forces to work with farmers, rural leaders, and energy advocates to build a stronger base of support for renewable energy development in the state. The goals of the project are to broaden the base of support for renewable energy, to develop as much renewable electricity in the state as possible, to sustain existing momentum despite increasing market pressure against renewables, and to do this in ways that provide direct benefits to the host rural communities. SEED has assembled a comprehensive list of the benefits of renewable energy (see Table A2-2 below). Most of the cited benefits apply to Hawaii.

C. Nevada

The State of Nevada prepared a thorough economic analysis of the costs and benefits of a renewables portfolio standard. The results of this economic analysis provided factual support for RPS with the State's legislature. The economic impact study conducted for the state by the Corporation for Solar Technology and NREL revealed that the RPS would create 500 jobs, about $150 million in wage and state tax revenue, and reduce global warming CO_2 emissions by 2 million tons by 2010.[55] When economic development benefits are considered, the study results showed that the Portfolio Standard yielded a net gain to the Nevada economy.

D. Wisconsin

The State of Wisconsin Department of Administration used a dynamic macroeconomic model of the Wisconsin economy to estimate the economic impacts of displacing a portion of future investment in fossil fuel power plants (coal and natural gas)

[55] E-mail communication to GDS from Terri Walters of the National Renewable Energy Laboratory, November 30, 2000.

with renewable energy resources (biomass, wind, solar and hydro).[56]

Table A2-2. Renewable Energy Benefits Cited by Minnesota Sustainable Energy for Economic Development Project
FOR EVERYONE • Provides cheap, clean and reliable electricity. Renewable energy resources can be developed in an economically efficient and environmentally safe way. Renewables can potentially produce more than enough electricity to meet the energy needs of the state. The most promising Minnesota renewables are wind energy, biomass energy and solar energy from photovoltaics (PVs). • Creates little or no pollution or waste. Air pollution, land damage from coal mining, contamination of water supplies, global warming and deadly radioactive nuclear waste are the results of coal and nuclear power production, which currently generate nearly all of the state's electricity. Renewables possess minimal environmental risk. • As renewable energy technology progresses, performance continues to improve and price continues to decline. Coal-fired electricity has seen no significant improvement in price or performance in 30 years; and oil is very susceptible to future price increases. • Develops an energy source that cannot be depleted. Because wind, biomass, and PV resources are dependent only on the sun's energy, their supply will not be depleted by use.
FOR UTILITIES • Provides customers with the clean and reliable electricity they want. Numerous surveys show that customers have a strong preference for clean energy and are willing to pay more for that energy. • Creates a diverse electricity supply. By adding diversity to its electricity supply, utilities can gain valuable experience with the technologies of the future. • Protects against future environmental regulations and pollution taxes and increases price stability. Renewable energy ensures against price increases due to environmental protection. Because most renewables produce no emissions or waste, there is no future risk of price hikes due to environmental externalities. • Lowers risks because additional energy capacity is manufactured incrementally. As energy demand increases, wind, biomass and PV generation can be added in small stages without the large scale, long-term investments required in constructing oil and coal power plants.
FOR RURAL COMMUNITIES • Allows farmers to diversify the types of crops they grow and the markets they sell them to. The farmer's risk of downswings in other crop markets is decreased with investment in production of energy crops or leasing of farmer's land for such renewable resources as wind. • Revitalizes rural economic development. Energy dollars that once were sent out of the area can now remain in the community where they are earned. • Creates more jobs, earnings, and sales than any other energy production. According to the New York State Energy Office, wind energy systems create 25 to 70% more jobs than conventional power plants producing the same amount of electricity. • Increased independence from large corporations. Rural communities will have the ability to become energy self-reliant and have more control over the energy source used and the price that is paid for electricity. • Increases civic pride. Local renewable energy projects will boost community involvement and demonstrate an example for other communities.

Wisconsin's modeling results show that renewable energy investments produce over three times more jobs, income and economic activity than the same amount of electricity generated from coal and natural gas power plants.

Between 1995 and 2020, a 75% increase in renewable energy use generated

[56] State of Wisconsin, Department of Administration. *Fueling Wisconsin's Economy With Renewable Energy*. Paper prepared by Steve Clemmer, Wisconsin Energy Bureau, 1995.

approximately 65,000 more job-years of employment, $1.6 billion greater disposable income and a $3.1 billion increase in gross regional product than conventional power plant investments. This includes the effects of a 0.3% average annual increase in electricity prices from renewable energy investments.

A summary of renewable energy requirements that have been implemented in the U.S. is shown in Table A2-3 below. This table provides a detailed description of the various requirements that have been implemented including the authority for the standard (law, regulation, etc.), the requirements of the standard, the types of qualifying technologies, funding for the program, and additional comments.

Table A2-3. States with Renewable Energy Requirements

State	Authority	Technology / Requirements / Comments	Funding
Arizona	The Arizona Corporation Commission approved the "Solar and Environmentally Friendly Portfolio Standard" 4/26/2000.	Technology: In-state solar PV and solar thermal electric Requirements: 1.1% of utility electricity from solar by 2007 (starts with 0.4% by Jan. 1, 2001). Comments: Extra credits for in-state development, manufacturing, distributed power, early installation.	Funding is from utility bill surcharges and systems benefit charge.
Connecticut	Law – H.5005 Licensing regulations involving RPS complete (Docket # 98-0615) Law revised in 1999 (HB 6621)	Technology**:** <u>Class 1</u> Technologies: solar, wind, hydro, sustainable biomass, landfill gas, fuel cells. <u>Class 2</u> Technologies: hydro, MSW, other biomass Requirement: (% of sales) <u>Class 1 or 2</u>: 5.5% in 2000; 6% in 2005; 7% in 2009. <u>Class 1:</u> 0.5% in 2000 +0.25%/yr to 1% by 2002 +0.5%/yr to 3% by 2006 + 1%/yr to 6% in 2009. Comments: • Law allows state to implement credit trading program. • Does not apply to municipal and cooperative utilities. • 1999 revision to law allows DPUC to delay the RPS targets by up to 2 years if it finds that requirements cannot reasonably be met. • 1999 DPUC decision to exempt standard offer service from meeting RPS is under appeal. • Funding through a non-bypassable wires charge.	Total Funding = $22 million; Mils/kWh=0.75 ; 0.75% of revenue
Iowa	Law: Alternate Energy Production Law 1983, revised 1991.	Technology: Solar, wind, methane recovery, biomass Requirement: 105 average MW, 2% of 1999 sales Comments: • Applies to investor-owned utilities (IOUs) only • 250 MW of mostly wind installed	

Table A2-3. States with Renewable Energy Requirements			
State	**Authority**	**Technology / Requirements / Comments**	**Funding**
Maine	Law: LD1804 and Public Law Chapter 316 Regulations final Docket 97-584, law revised in May 1999	Technology: Fuel cells, tidal power, solar, wind, geothermal, hydro, biomass and municipal solid waste (MSW) (under 100 MW) High efficiency cogeneration systems of unlimited size Requirement: 30% of sales in 2000 (start of competition) Comments: • Renewables currently 46-51% of generation • PUC makes recommendations for changes to legislature no later than 5 years after beginning of retail competition • No credit trading • RPS to be met on a product basis • A recent RFP revealed a 5-10% premium for meeting Maine's RPS • Many qualifying projects are biomass • RPS supported by Maine Electricity Coalition and Independent Energy Producers of Maine	
Massachusetts	Law: Chapter 164 of the Acts of 1997 Scheduled to begin RPS design in fall 1999	Technology: Solar, wind, ocean, clean biomass. Hydro and MSW qualify as existing, but not as new renewables Requirements: State to determine existing renewables by 12/31/99 (approx. 7%); +1% from new renewables by 2003; +0.5%/yr to 4% by 2009; +1% per year thereafter until date determined by Division of Energy Resources Comments: • +1% new renewables requirement may start one year after any renewable within 10% of average spot market price of electricity. • Language ambiguous as to whether requires support for existing level of renewables. • Does not apply to municipal and cooperative utilities	Total Funding =$30 million; Mils/kWh = 0.7; 0.07% of revenue
Minnesota	Radioactive Waste Management Facility Authorization (1994) Minn. Stat. 216B.2423 MN PUC order Docket E-002/RP-98-32	Technology: Wind (825 MW) and biomass (125 MW) Preference for in-state projects Requirements: 550 MW by 2002; 400 MW more wind by 2012 (4.8% of 2012 sales) Comments: • Northern States Power allowed to build temporary dry cask storage of nuclear waste at Prairie Island nuclear plant in exchange for renewable energy development. • 1999 PUC order determined 400 more MW of wind by 2012 was in the public interest.	

Table A2-3. States with Renewable Energy Requirements			
State	**Authority**	**Technology / Requirements / Comments**	**Funding**
Nevada	Implementation Task Force underway Nevada PUC considering comments filed in March 1999. Nevada law enacted in 1997 for RPS – Deregulation: Assembly Bill 366 (www.leg.state.nv.us) PUC will establish docket for rulemaking	Technology: 50% from solar, 50% from wind, biomass, geothermal in state. Solar hot water eligible. Requirements: 0.2% in 2001, rising 0.2% biannually of 1% in 2009 Comments: • Applies to IOUs and independent power producers (IPPs), but not cooperatives, municipal utilities or general improvement districts. • Utilities with 9% or more of their electricity coming from renewables in 1997 are deemed to be in compliance until 2005. One utility exempted until 2005. • Major supporters of legislation were the National Renewable Energy Laboratory and the Nevada Consumer Advocate • Economic analysis developed to show benefits of RPS	
New Jersey	Restructuring law passed in January 1999	Technology: <u>Class I</u>: solar, wind, fuel cells, geothermal, wave, tidal energy, landfill gas, sustainable biomass. <u>Class II</u>: MSW or hydro that meets high environmental standards. Requirements: Class I or II Technologies 2.5%. 0.5% more from Class I by 2001; 1% by 2006 and increasing by 0.5%/yr to 4% by 2012 Comments: • Standard applies to retail and basic generation suppliers. • Credit trading jointly implemented by NJ Board of Public Utilities and NJ Department of Environmental Protection. • Funding via a surcharge on the wires charge, the same as existing demand-side management (DSM) costs. 25% of new units must be renewable. • Major supporters: NRDC, utilities, and environmental groups.	Total Funding =$30 million; Mils/kWh=0.45; 0.45% of revenues
Pennsylvania	Being addressed in individual utility restructuring cases.	Technology: Non-hydro renewables Requirements: For PECO, West Penn, and PP&L, 20% of residential customers served by competitive default provider; 2% in 2001, increasing 0.5%/yr. For GPU, 0.2% in 2001 for 20% of customers increasing to 80% in 2004. Comments: Requirement imposed on service-territory basis.	Total Funding=$2 million Mils/kWh=0.02; 0.02% of revenue

Table A2-3. States with Renewable Energy Requirements			
State	**Authority**	**Technology / Requirements / Comments**	**Funding**
Texas	Senate Bill 7 (www.capitol.state.tx.us/cgi-bin/tlo/) Draft regulations published 10/99. Regulations were adopted in December 1999.	Technology: Solar, wind, geothermal, hydro, wave, tidal, biomass, biomass-based waste products, including landfill gas Requirements: New & existing renewables: 1,280 MW by 2003; 1,730 MW by 2005; 2,280 MW by 2007; 2,880 MW by 2008 (existing = 880 MW, approx. 2.3% of 2009 sales) Comments: • Commission to establish credit trading program • Munis and co-ops subject to requirement if they opt in to retail competition. • Draft regulations require 2,000 MW new renewables by 2009 and energy-based standard. • Facilities installed after 1995 are eligible for credits (above the 2,000 MW requirement).	Total Funding over $15 million; Mils/kWh =0.065; Revenue = 0.1%+
Wisconsin	Act 9 of 1999 (legislation passed November 1, 1999)	Technology: Wind, solar, biomass, geothermal, tidal, a fuel cell that uses a renewable fuel, hydro under 60 MW. Requirements: 0.5% by 2001, increasing to 2.2% BY 2011 (0.6% can come from facilities installed before 1/1/98) Comments: • 50 MW new renewables by 2000 (included in 1998 Reliability Act) are eligible. • IOUs, munis, and co-ops are subject to the requirement. Northern States Power excluded. • First state to adopt RPS without retail competition. • Legislation was supported by a coalition of environmental organizations and small utilities. Renew Wisconsin was a key supporter. • A $500,000 penalty may be assessed for non-compliance. • Wisconsin Electric Power has issued an RFP for 75 MW of renewable capacity.	Total Funding =$3.8 million; Mils/kWh =0.1; 0.15% of revenue