

## **1.0 Executive Summary**

The objective of this study is to identify the best options for renewable energy development on the island of Kauai. Kauai Island Utility Cooperative (KIUC) has retained Black & Veatch to undertake this assessment of renewable energy technologies and potential projects. This summary provides a comprehensive overview of this Final Report.

### **1.1 Introduction**

In 2003, over 94 percent of Kauai's electricity was generated from imported fossil fuels – the highest level of fossil fuel dependence in over 25 years. This coincides with a period of record oil prices, political and military strife, and concerns about impacts on the global environment from increased consumption of fossil fuels. At the same time, Kauai is blessed with rich indigenous resources and historical experience using renewable energy sources to meet a large share of its energy needs.

This study examines a return to renewable energy resources as part of KIUC's upcoming Integrated Resource Plan (IRP) filing. In addition, KIUC anticipates utilizing the results of this study to develop a strategy to meet the renewable portfolio standard (RPS) established by the Hawaiian legislature. This standard calls for 20 percent of electricity to be generated from renewable sources by 2020. Accounting for solar water heating, KIUC sourced 7.5 percent of its energy from renewable resources in 2003. While on pace for the 2020 goal, Kauai's reliance on renewable resources has steadily been declining. In the early 1980s, hydro and biomass accounted for upwards of 40 to 50 percent of electricity generated on the island. This energy came largely from sugar mills. As the sugar industry has declined, so has Kauai's primary source of renewable energy.

This study is being undertaken in two phases. This Final Report is a comprehensive account of both. An Interim Report covered Phase 1, describing the existing use of renewable energy on the island, generation technology options, and the developable potential of the different resources. The Interim Report reviewed a broad range of renewable energy technologies and concluded with the scoring of the technology options and recommendations for further study in Phase 2. Phase 2 of the project characterizes the most promising options in greater detail and identifies specific projects for possible implementation.

### **1.2 Renewable Technology Options**

Twenty six renewable and advanced energy technologies were assessed in Phase 1. The technologies were split into ten categories as follows:

1. Solid biomass (p. 3-3)
  - 1.1 Direct fired**
  - 1.2 Cofiring
2. Biogas (p. 3-14)
  - 2.1 Anaerobic digestion
  - 2.2 Landfill gas**
3. Biofuels (p. 3-21)
  - 3.1 Ethanol
  - 3.2 Biodiesel
4. Waste to energy (p. 3-32)
  - 4.1 Mass burn**
  - 4.2 Refuse derived fuel
  - 4.3 Plasma arc
- 5. Hydroelectric (p. 3-42)**
6. Ocean energy (p. 3-47)
  - 6.1 Ocean thermal energy conversion
  - 6.2 Wave
  - 6.3 Tidal
7. Solar (p. 3-57)
  - 7.1 Solar photovoltaic
    - 7.1.1 Residential
    - 7.1.2 Commercial
  - 7.2 Solar thermal
    - 7.2.1 Parabolic trough
    - 7.2.2 Parabolic dish stirling
    - 7.2.3 Central receiver
    - 7.2.4 Solar chimney
- 8. Wind (p. 3-67)**
  - 8.1 Wind farm
  - 8.2 Distributed wind
9. Geothermal (p. 3-74)
10. Multi-fuel generation technologies (p. 3-76)
  - 10.1 Reciprocating engines
    - 10.1.1 Spark ignition
    - 10.1.2 Compression ignition
  - 10.2 Small combustion turbines
  - 10.3 Microturbines
  - 10.4 Fuel cells

*(Page references for the technology screening section are shown in parentheses. The five technologies carried forward for detailed analysis are underlined.)*

Generally, each technology was described with respect to its principles of operation, applications, resource characteristics, cost and performance, environmental impacts, and outlook for Kauai. The outlook for Kauai included an assessment of the potential developable resource within the next 3, 5, 10 and 20 years.

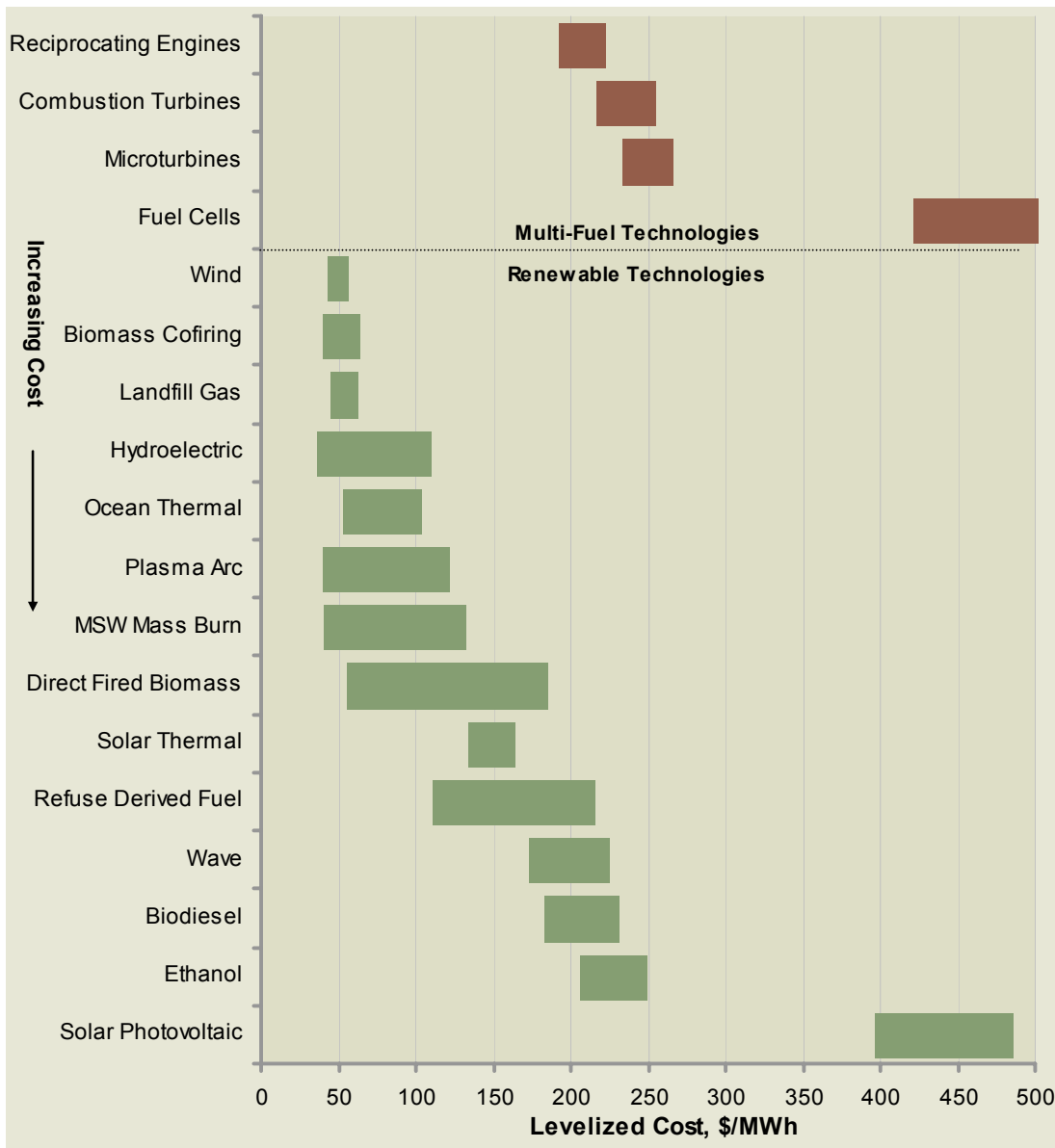
### **1.3 Renewable Energy Technology Screening**

A technology screening methodology was used to evaluate, rank and select Kauai renewable energy resources for further investigation. The assessment methodology employs a set of seven weighted criteria:

- Cost of energy (50 percent)
- Kauai resource potential (10 percent)
- Fit to KIUC needs (10 percent)
- Technology maturity (10 percent)
- Environmental impact (7.5 percent)

- Socioeconomic impact (7.5 percent)
- Incentives/Barriers (5 percent)

Cost of energy accounts for 50 percent of the overall screening score, with the rest of the criteria contributing varying degrees to the remaining 50 percent. As some of the scores will change over time as a technology matures or KIUC's needs change, screening of technologies was done at intervals of 3, 5, 10 and 20 years in the future. Highlights of the screening include the cost of energy (Figure 1-1) and Kauai resource potential (Figure 1-2).



**Figure 1-1. Range of Levelized Cost for Renewable Technologies (Three Year Timeframe).**

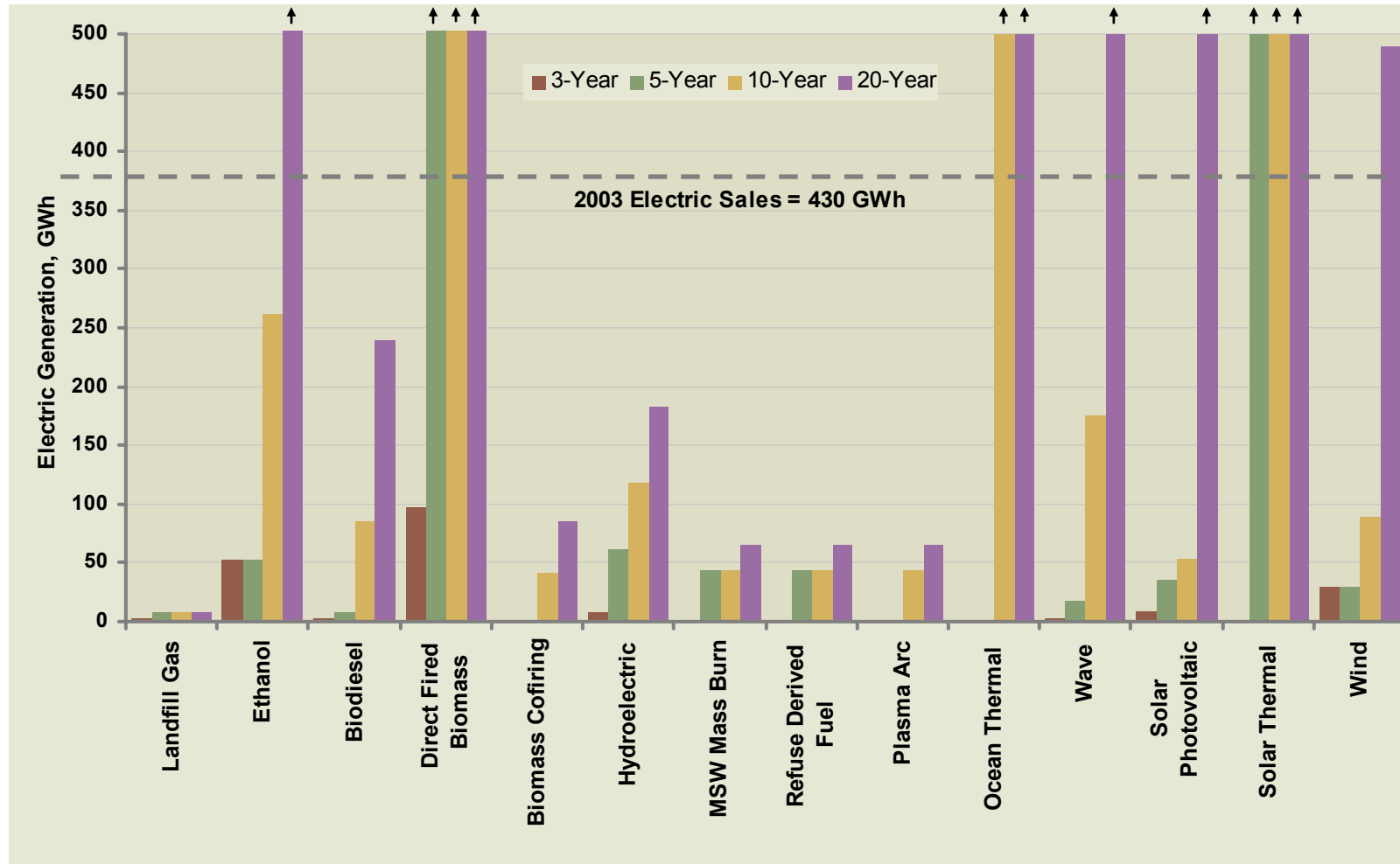


Figure 1-2. Developable Potential of Kauai Renewable Resources (Annual Generation, GWh/yr).

The cost of energy results demonstrate that there are numerous technologies with generation costs below \$100/MWh (10 cents/kWh), which is lower than KIUC's current avoided energy cost. Low cost options include wind, biomass cofiring, hydro, municipal solid waste (MSW), and landfill gas.

The Kauai resource potential results demonstrate that in addition to there being numerous low cost power options, renewable resources are abundant on Kauai. There are several resources that could theoretically meet all of Kauai's electrical energy needs, which totaled about 430 GWh in 2003. These include direct fired biomass and solar thermal in the near term, and in the long term, ethanol, ocean thermal, ocean wave, solar photovoltaic, and wind. Biodiesel and hydroelectric also have good potential.

The cost of energy and resource potential criteria were combined with the other measures and applied over 3, 5, 10 and 20 years. The results for each period are shown in Figure 1-3. In general, the scores trend upward over the 20 year evaluation period. The reasons for this are improvements in cost of electricity, developable resource, and technology maturity. Based on the results of the screening analysis, Black & Veatch recommended that landfill gas, wind, hydro, direct fired biomass, and MSW mass burn be examined in Phase 2. KIUC concurred with this recommendation.

Following a discussion of renewable energy financial incentives, the remainder of this section summarizes the project assessments performed for these five technologies. Selected project locations are shown in Figure 1-4.

## **1.4 Renewable Energy Financial Incentives**

A number of state and federal renewable energy development incentives were examined for applicability to KIUC and the types of projects analyzed in Phase 2. There are two basic types of incentives, tax related and non-tax related, such as grants and green pricing programs. The primary means by which the federal government has supported the development of renewable energy is through the production tax credit (PTC), reduced depreciation life, and the renewable energy production incentive (REPI). After a recent expansion, the PTC now provides \$18/MWh (inflation adjusted) for wind, solar, geothermal, and closed loop biomass. The PTC is also available at \$9/MWh for open-loop biomass, small hydro, and municipal waste. Wind and closed-loop biomass receive PTC for 10 years, other technologies receive credit for 5 years. The reduced depreciation life incentive allows taxable entities to depreciate some renewable energy equipment over a period of five years. REPI provides for payments of about \$18/MWh to public utilities and governmental entities for the production of renewable energy; however, this credit expired at the end of 2003.

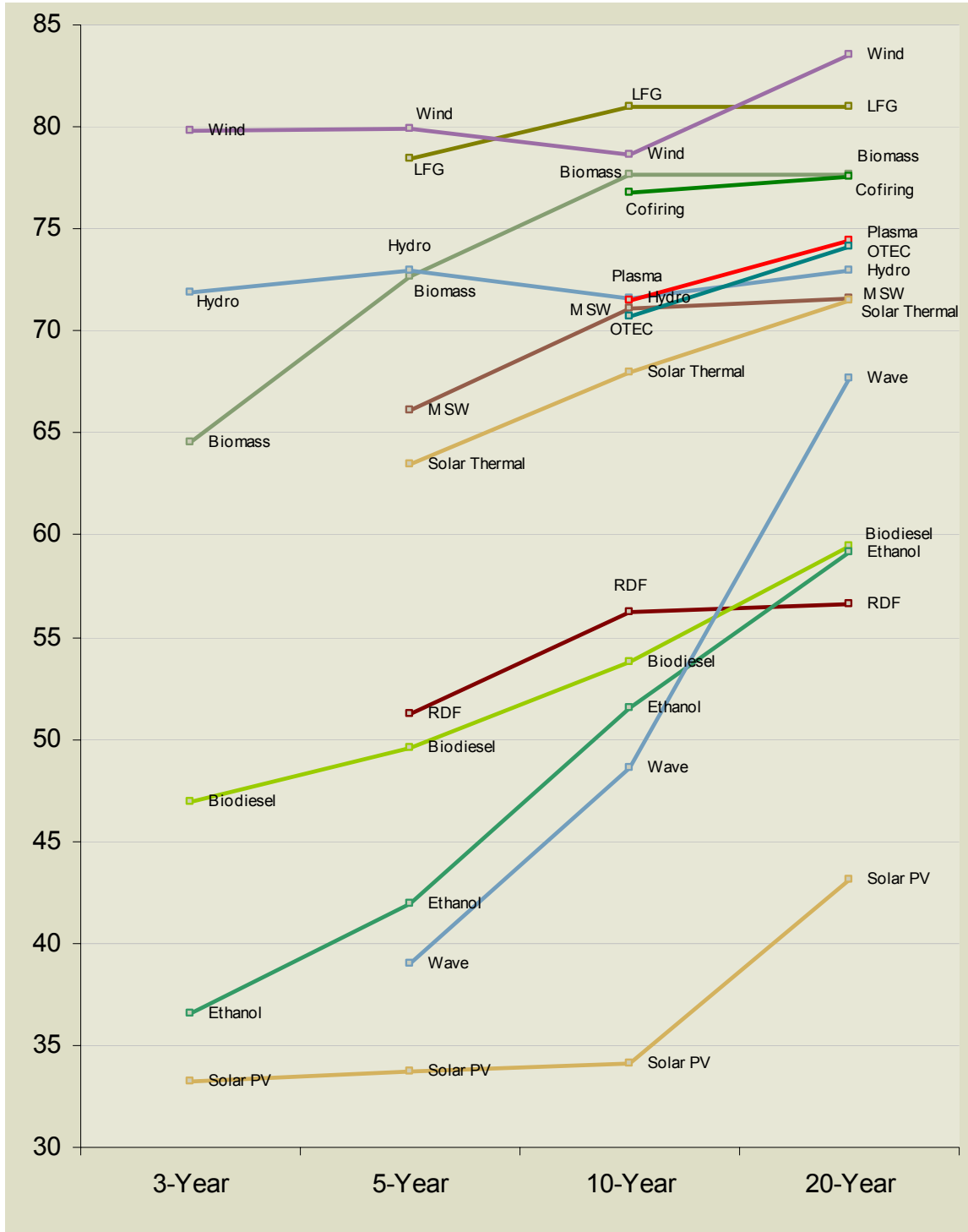


Figure 1-3. Change in Technology Screening Scores by Timeframe (max=100).

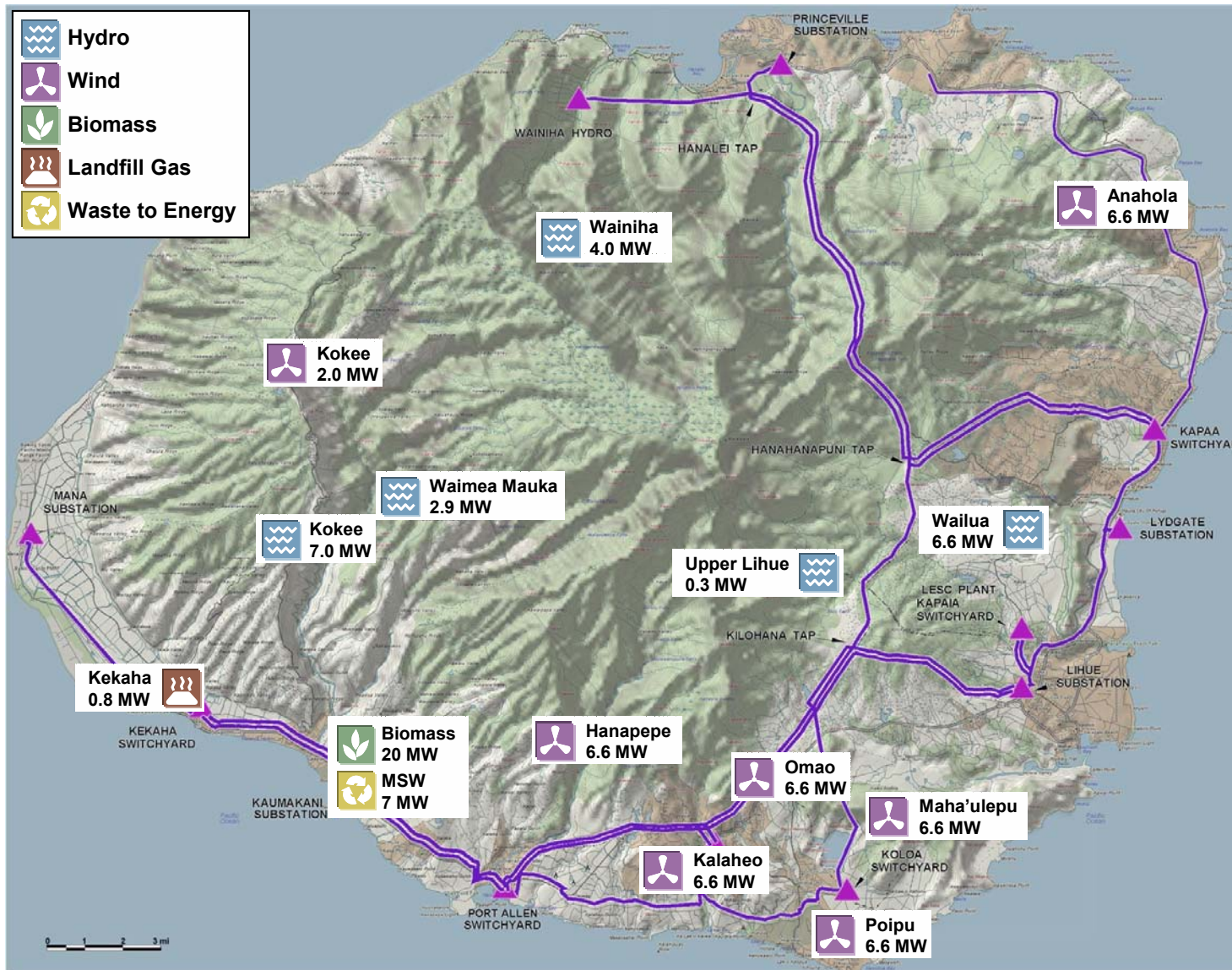


Figure 1-4. Selected Project Locations.

The production tax credit is an attractive incentive that applies to most of the projects profiled in detail in this report. Although the federal tax incentives typically are only available to taxable entities, there are project structures which may allow KIUC to partner with private entities. In this manner, KIUC could finance the project with its low cost financing, while the taxable entity could take advantage of the value of the tax credits. Further financial and legal review would be required by KIUC, but if tax credits continue to be offered for the next five to eight years, this ownership structure could be an interesting option for KIUC to consider.

Various grants offered by the federal government and available to public utilities and governmental entities were also identified. With residential rates at about triple the national average, KIUC would qualify for the USDA High Energy Cost Program. KIUC could also receive funding under provisions of the 2002 Farm Bill supporting renewable energy development. Additionally, from time to time grants are also available from the Department of Energy and other agencies for development and demonstration projects. Any of these programs could potentially provide in excess of \$1 million towards the development of a project. These grants are offered to provide assistance for areas with high electric rates, tribal economic development, renewable technology demonstration, and various other policy or technology objectives. Funding for these grant programs can change significantly from year to year, and policy objectives of the organizations that offer grants change over time; therefore, it is difficult to predict the amount of funds available from a particular program for a particular project. In any case, before project development activities proceed, opportunities for grant funding should be identified and pursued.

Green pricing and renewable energy credits may be viable methods for KIUC to capture additional value from renewable generation. Utility green pricing programs allow customers that want more renewable energy to pay a small premium on monthly electricity bills to support renewable development. Renewable energy credits are tradable credits that represent the “green attributes” of renewable energy. These credits can be sold to voluntary purchasers (such as the federal government) or used to meet mandatory targets established by renewable portfolio standards. If KIUC has excess renewable energy, it might be able to sell excess credits to other Hawaiian utilities.

The remainder of this executive summary reviews key findings for the five technologies which passed the Phase 1 screening. Economic analysis is performed assuming all projects come online in 2009.

## 1.5 Biomass and Municipal Solid Waste

Biomass project sizes from 5 to 30 MW were considered, and an optimum size of 20 MW was selected based on preliminary technical and economic analysis. The biomass fuel mix and cost change based on the project size. Smaller projects can utilize lower cost waste biomass resources (wood chips, bagasse, and cane trash), while larger projects would need to rely on dedicated energy crops such as banagrass (elephant grass). A stoker boiler was selected as the basis for the project conceptual design due to its good mix of technical maturity, efficiency, and cost. The location for the biomass project has not been specified yet.

After selecting 20 MW as the preferred size for the biomass project, capital and O&M costs and plant performance were estimated to determine cost of energy for such a plant for KIUC. The life-cycle costs were analyzed using the likely low, high and mid range fuel costs to establish upper and lower bounds for the analysis. The results of these estimates are shown in Table 1-1.

<b>Table 1-1. Biomass Life-Cycle Economic Assumptions (\$2005).</b>				
	<b>Unit</b>	<b>Low Fuel Cost</b>	<b>Mid Fuel Cost</b>	<b>High Fuel Cost</b>
Capacity	MW	20.0	20.0	20.0
Capital Cost	\$/kW	4,556	4,556	4,556
First Year Fixed O&M	\$/kW-yr	150	150	150
First Year Variable O&M	\$/MWh	8.4	8.4	8.4
First Year Fuel Cost	\$/MBtu	3.50	4.15	4.57
Net Plant Heat Rate	Btu/kWh	15,397	15,397	15,397
Capacity Factor	percent	80%	80%	80%
KIUC Levelized Cost	2009\$/MWh	179.5	194.8	204.6
KIUC Premium*	2009\$/MWh	5.6	20.9	30.7

\*Electricity cost premium (or savings) compared to KIUC's forecasted avoided costs.

Based on the assumptions shown in Table 1-1, the levelized cost of electricity can be calculated. The levelized electricity cost includes all costs to generate power (capital, O&M, fuel, etc.) levelized over the life cycle of the project. In 2009, it is projected that the levelized cost of supplying power from a biomass fueled power station would range from \$180/MWh to \$205/MWh, depending on the fuel cost. This cost can be compared to the cost of KIUC's existing resources and projected new unit additions. These costs would be "avoided" if the biomass plant were built. Based on avoided cost forecasts from KIUC, biomass is able to avoid \$174/MWh in energy and capacity costs on a levelized basis (2009\$). Taking these costs into account, the premium for biomass ranges

from \$5.6/MWh to \$31/MWh over avoided costs. The biomass power station does not compare favorably with the forecasted avoided costs because the fuel is expensive, the plant is relatively inefficient, and the capital costs are high.

The levelized cost for biomass is higher than the range predicted in the first phase of the report (up to \$186/MWh, see Table 3-1). The technology screening was done at a high level resulted in very broad, generic estimates of cost. As biomass was investigated in more detail, there were several changes that drove up the estimated cost of the facility. These include examining a smaller size, adding capability to burn multiple fuels, higher fixed O&M costs (largely labor), slightly poorer efficiency, and other factors. These factors combined to raise the price range of biomass outside of initial expectations.

Various technology options for waste to energy were compared in the screening section of the report, and it was determined that mass burn was the preferred conversion technology. Similar to biomass, no specific project size was identified for analysis, so the screening phase focused on selecting an appropriate size for the plant. A screening level analysis compared the cost of energy for various sized plants at the current (\$56/ton) and possible future (\$90/ton) tipping fee. Two project sizes, 200 and 300 tons per day, were evaluated. Due to economies of scale, it was determined that the 300 ton per day facility was the better choice economically, even if it had to purchase 100 tons per day of higher cost biomass to supplement the 200 tons per day of waste.

After selecting 300 tons per day (7.3 MW) as the preferred size for the MSW project, capital and O&M costs and plant performance were estimated to determine cost of energy for such a plant for KIUC. The life-cycle costs analyzed using the likely low, high and mid range fuel costs to establish upper and lower bounds for the analysis. The results of these estimates are shown in Table 1-2.

**Table 1-2. MSW Life-Cycle Economic Assumptions (\$2005).**

	<b>Unit</b>	<b>\$56/ton Tipping Fee</b>	<b>\$70/ton Tipping Fee</b>	<b>\$90/ton Tipping Fee</b>
Capacity	MW	7.3	7.3	7.3
Capital Cost	\$/kW	11,343	11,343	11,343
First Year Fixed O&M	\$/kW-yr	286.0	286.0	286.0
First Year Variable O&M	\$/MWh	23.1	23.1	23.1
First Year Fuel Cost	\$/MBtu	(5.09)	(6.36)	(8.18)
Net Plant Heat Rate	Btu/kWh	18,744	18,744	18,744
Capacity Factor	percent	70%	70%	70%
KIUC Levelized Cost	2009\$/MWh	108.66	72.38	20.39
KIUC Premium	2009\$/MWh	(68.00)	(104.28)	(156.27)

The range of tipping fees was selected to account for the current tipping fees at the Kekaha landfill (low), and estimated costs of disposal at a new landfill (high). The table shows that the relatively high cost of constructing and operating a waste-to-energy facility is compensated for by the high tipping fees paid to the plant to accept waste. The levelized cost of energy generation with KIUC ownership ranged from a very low \$20/MWh to \$109/MWh, depending on tipping fee assumptions. Compared to KIUC's forecasted avoided costs, the cost premium ranged from (\$156)/MWh to (\$68)/MWh. Assuming the \$90/ton tipping fee is available, the MSW plant has the best economics of any of the alternatives studied in this project.

In addition to standalone biomass and MSW, a plant that combines both fuels was considered. Different equipment configurations were evaluated and a preferred approach and size characterized. For further information, please refer to Section 7 of the report. The economics of such a plant are between the standalone biomass and MSW options.

## **1.6 Hydro**

Previous assessments identifying potential hydro projects on Kauai were reviewed and 49 possible project sites were cataloged. From this list, six promising projects were selected and characterized. The projects are located throughout the island and consist of four new sites and two upgrades of existing facilities. All the sites are run-of-river or run-of-ditch, which minimizes potential negative environmental impacts. The projects are summarized in Table 1-3.

The variability in project site requirements for hydro leads to broad ranges of potential costs. For hydropower projects, much of the cost is often off-site from the power plant in the diversion structures, penstock, and their associated access roads. For this reason, it is difficult to develop generic estimates of project costs without detailed site studies, and estimates from past studies, despite their age, are preferred. On this basis, capital and O&M costs were developed, as shown in Table 1-4.

No.	Project Name	Status	Type	Static Head (ft)	Design Flow (cfs)	Plant Size (kW)		
						Exist.	Prop.	Total
1	Wainiha	new	run-of-river	433	139	0	4,000	4,000
2	Upper Lihue	upgrade	run-of-river	247	32	500	300	800
3	Wailua	new	run-of-river	262	150	0	6,600	6,600
4	Waimea Mauka	upgrade	run-of-river	265	55	1,000	2,900	3,900
5A	Puu Lua-Kitao	new	run-of-ditch	1,145	40	0	2,970	2,970
5B	Kitano-Waimea	new	run-of-ditch	2,093	30	0	4,078	4,078

	Unit	Wainiha	Upper Lihue	Wailua	Waimea Mauka	Puu Lua-Kitano	Kitano-Waimea
Capacity	MW	4	0.3	6.6	2.9	2.97	4.078
Capital Cost	\$/kW	4,496	7,248	2,044	1,213	5,933	3,955
First Year Fixed O&M	\$/kW-yr	67.5	101.8	31.1	27.7	89.6	61.6
First Year Variable O&M	\$/MWh	N/A	N/A	N/A	N/A	N/A	N/A
First Year Fuel Cost	\$/MBtu	N/A	N/A	N/A	N/A	N/A	N/A
Net Plant Heat Rate	Btu/kWh	N/A	N/A	N/A	N/A	N/A	N/A
Capacity Factor	percent	64%	69%	28%	15%	61%	48%
KIUC Levelized Cost	2009\$/MWh	58.4	86.1	60.4	79.1	81.8	69.9
KIUC Premium	2009\$/MWh	(116.3)	(88.6)	(114.4)	(95.7)	(93.0)	(104.8)

The levelized cost of generating power from the six projects ranged from \$58/MWh for Wainiha to \$86/MWh for Upper Lihue assuming KIUC ownership. Compared to KIUC's forecasted avoided energy costs, the levelized cost premiums ranged from (\$116)/MWh to (\$89)/MWh. The negative premium indicates that developing these resources is less expensive than the forecasts of KIUC's avoided costs. The best project appears to be the Wainiha project, which had undergone extensive development in the 1980s before being halted due to low power prices. It is noted that more than the other technologies, KIUC ownership of hydro projects may not be feasible in all situations. KIUC will need to work closely with other parties to ensure the most appropriate arrangement.

## 1.7 Wind

Using the preliminary wind resource map of Kauai as a guide, eleven areas for potential wind projects were identified. Each was examined in light of its location, wind resource and other factors as discussed with KIUC. The locations were rated as high, moderate, or low priority for continued development, as shown in Table 1-5. Seven areas were ranked as having a high or moderate priority and were studied in further detail using the validated wind map, available on-site wind data, Black & Veatch cost data, and other resources.

**Table 1-5. Project Option Screening.**

Area	Construct-ability	Trans-mission Access	Potential MW	Wind Class	Capacity Factor	Suitable for Dist. Project?	Priority
1: Kalaheo	good	good	100+	4-5	35%	yes	high
2: Omao	fair	good	15-55	5-6	34-40%	yes	moderate
3: Waialeale	bad	bad	100+	6-7	40%+	no	low
4: Kuahua	bad	bad	50	5-7	35-40%	no	low
5: Hanapepe	fair	fair	100+	5-7	36%	no	moderate
6: Kokee	good	fair	15	5-6	35-38%	yes	moderate
7: Kalalau	bad	bad	100+	6-7	40%+	no	low
8: Anahola	fair	fair	25	4-6	34%	yes	high
9: Poipu	good	good	100+	3-5	30-33%	yes	moderate
10: Maha'ulepu	fair	good	10-100	5-6	34-40%	no	moderate
11: Offshore	bad	bad	100+	6	40%+	no	low

In general, abundant wind potential was found on Kauai, and several likely project sites were identified. It is not expected that resource availability would limit the amount of wind power that could be developed. Rather, the amount of wind generation that could be integrated with the utility grid would be the limiting factor. Key factors for selecting a site to develop include visual impact, community support, and constructability.

Table 1-6 provides a summary of the wind project performance and economic assumptions as well as the results of the life-cycle cost analysis.

**Table 1-6. Wind Life-Cycle Economic Assumptions (\$2005).**

	Unit	Kalaheo	Omao	Hana-pepe	Kokee	Anahola	Poipu	Maha'-ulepu
Capacity	MW	6.6	6.6	6.6	1.98	6.6	6.6	6.6
Capital Cost	\$/kW	1628	1689	1947	2249	1826	1628	1689
First Year Fixed O&M	\$/kW-yr	39.06	39.11	39.11	75.1	39.11	39.06	39.11
First Year Variable O&M	\$/MWh	1.73	1.68	1.68	1.73	1.78	1.95	1.68
First Year Fuel Cost	\$/MBtu	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Net Plant Heat Rate	Btu/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Capacity Factor	percent	35%	36%	36%	36%	34%	31%	36%
KIUC Levelized Cost	2009\$/MWh	64.46	64.24	70.76	95.88	71.68	72.77	64.24
KIUC Premium	2009\$/MWh	(90.10)	(90.32)	(83.80)	(58.68)	(82.88)	(81.79)	(90.32)

The levelized cost of generating power from the seven wind projects with KIUC ownership ranged from \$64/MWh to \$73/MWh for the 6.6 MW projects to \$96/MWh for the 2 MW project. No wind site stands out as being vastly superior to others. This gives KIUC good flexibility (and negotiation position) in siting the first projects in the location deemed most suitable. When the avoided capacity and energy costs were considered, the levelized cost premiums ranged from (\$90)/MWh to (\$59)/MWh. These results indicate that wind is attractive economically compared to KIUC's forecast of avoided costs.

## 1.8 Landfill Gas

Although the landfill at Kekaha does not currently have gas collection facilities, a landfill gas (LFG) project was studied to estimate the capacity that could be expected from the landfill. The gas production and corresponding power generation were estimated for a landfill closure date of 2009.

Data from the landfill suggests that the methane content of the LFG would be approximately 40 percent. The maximum LFG flow was estimated to be 465 cfm in 2009 with the production declining to 345 cfm in 2024. An 800 kW capacity LFG plant was considered appropriate for the resource.

A Caterpillar G3516 natural gas engine was used to estimate project capital and O&M costs and plant performance to determine cost of energy. The results of these life-cycle cost estimates and the resulting analysis are shown in Table 1-7.

**Table 1-7. Landfill Gas Life-Cycle Economic Assumptions (\$2005).**

	Unit	Kekaha Landfill
Capacity	MW	0.8
Capital Cost	\$/kW	3,965
First Year Fixed O&M	\$/kW-yr	111
First Year Variable O&M	\$/MWh	16
First Year Fuel Cost	\$/MBtu	-
Net Plant Heat Rate	Btu/kWh	11,491
Capacity Factor	percent	86%
KIUC Levelized Cost	2009\$/MWh	98.83
KIUC Premium	2009\$/MWh	(61.54)

The levelized cost of the landfill gas project was calculated to be about \$99/MWh, with a premium of about (\$62)/MWh. The favorable economics of the landfill gas project relative to forecasted avoided costs are due, in part, to the free fuel and the high capacity factor.

## 1.9 Final Renewable Energy Project Scoring

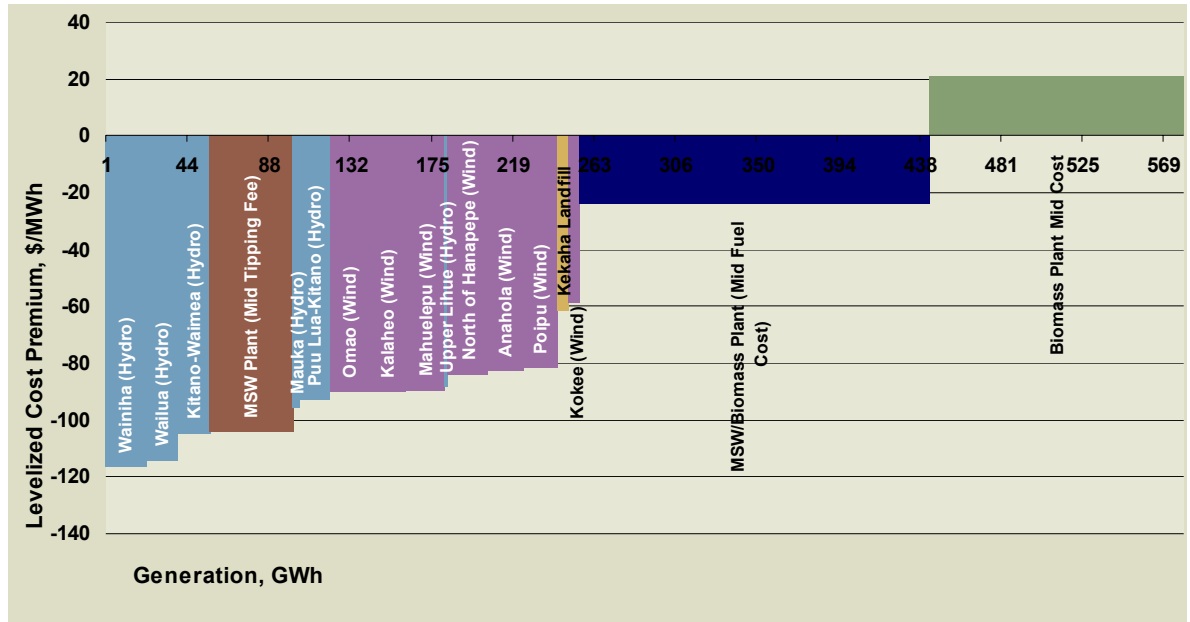
Based on the project characterizations from the previous section, the projects were scored with a scoring methodology similar to the technology screening in the Phase 1 analysis. The assessment methodology included the following weighted criteria:

- Levelized cost premium (50 percent)
- Kauai resource potential (10 percent)
- Fit to KIUC needs (10 percent)
- Technology maturity (10 percent)
- Environmental impact (7.5 percent)
- Socioeconomic impact (7.5 percent)
- Incentives/Barriers (5 percent)

The evaluation criteria were slightly modified from the initial analysis to better account for conditions affecting specific projects rather than general technologies. The most significant change is the measurement of projects by the levelized cost premium rather than the cost of energy. The levelized cost premium is equal to the levelized cost of energy less KIUC's forecasted avoided capacity and energy costs.

The levelized cost premium scoring revealed that nearly all of the proposed projects could be developed at a negative price premium (savings) relative to the forecasted avoided costs. Stated clearly, almost all the projects appear to be economically attractive. Figure 1-5 is a supply curve of the renewable energy options

available to KIUC. The curve shows the amount of generation available from each technology plotted against the levelized cost premium in ascending order. The lowest cost options (left side of chart) were revealed to be hydro and wind projects. The base case fuel prices are used for biomass and MSW options. An important conclusion from the supply curve is that about 400 GWh of renewable energy projects were identified by this study at a cost below KIUC's forecasted avoided costs. KIUC generated about 430 GWh in 2003, largely from fossil fuel resources.



**Figure 1-5. Levelized Cost Premium Supply Curve.**

The scores of the initial screening for resource potential were reused for the project analysis. These scores served as a measure of the replicability of a given project type over the next 20 years. For example, there is limited MSW resource on the island, but large wind resources.

The fit to KIUC needs category provided a measure of the applicability and suitability of a given project for KIUC. Projects receiving the highest scores were generally small in capacity and provided more energy than capacity to the system. This is because the KIUC system is “capacity rich” in the short term. The projects scoring highest in this category included the hydro and wind projects.

The level of environmental impact was scored for each project. There was a significant difference between the environmental impacts from projects even of the same technology. For example, the Upper Lihue hydro upgrade project has practical zero

negative environmental impacts, whereas the Wailua hydro project has significant environmental impacts because it requires development of a new resource.

The scores from the preceding categories were combined with the technology maturity, socioeconomic impact, and incentives/barriers scores to produce the final score for each project. Figure 1-6 shows the breakdown of the final scoring results. Hydro and wind projects were generally the highest scoring types of projects due to their relatively low cost, high suitability for KIUC, and minimal environmental impact. While the MSW and biomass projects offer considerable socioeconomic benefits, the cost and unsuitability for KIUC in the near-term caused these projects be scored lower. The exception is an MSW plant with a high tipping fee. The economics of such a project are very attractive and cause it to score highest of all projects evaluated. The economic viability of the project is dependent on high revenue from tipping fees, which may not be practicable.

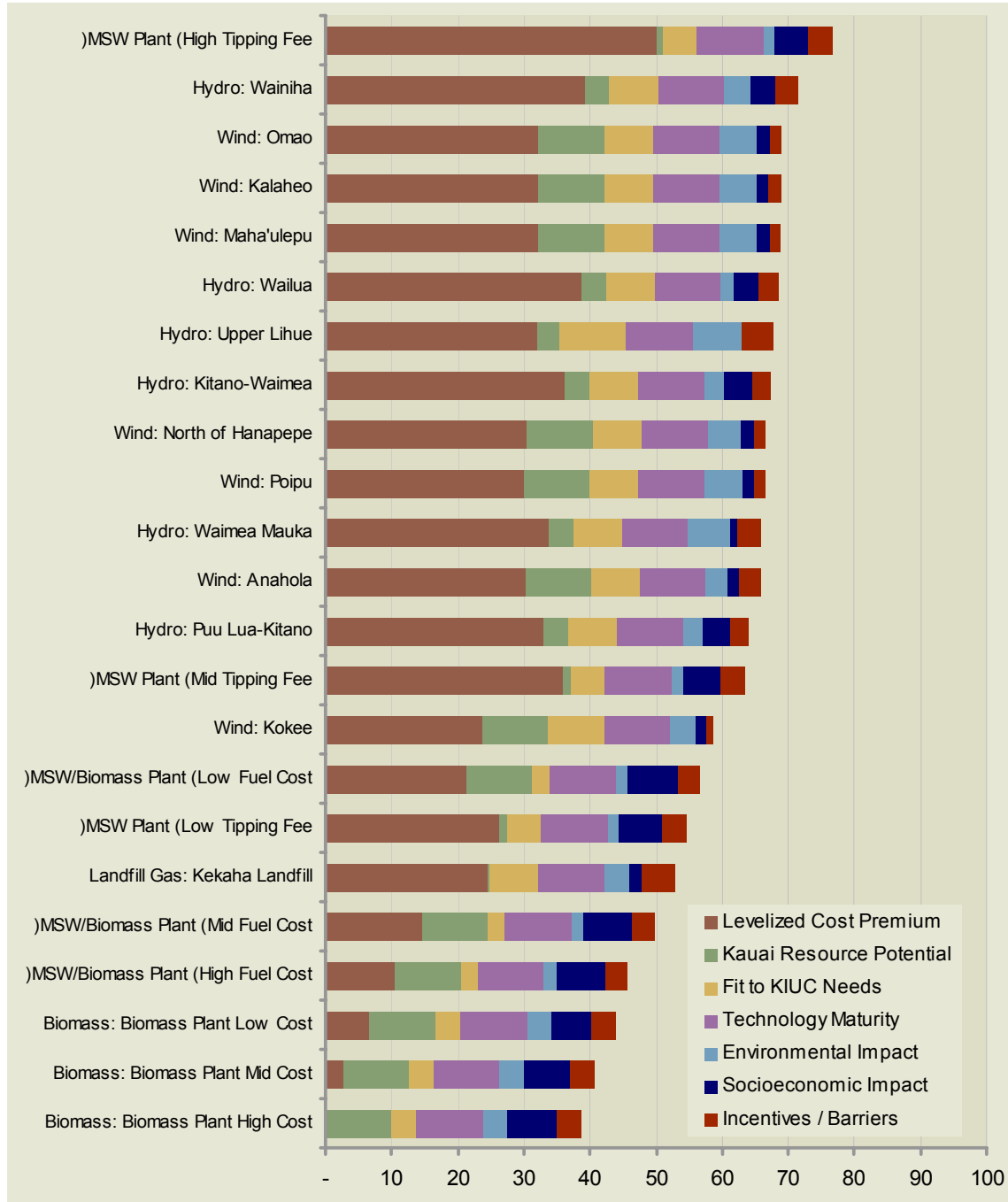


Figure 1-6. Scoring Results Breakdown.

## 1.10 Conclusions

The objective of this study is to identify the best renewable energy options for development on the island of Kauai. This project surveyed the renewable resources of Kauai and found that there are several commercial renewable energy resources that could reduce or eliminate Kauai's dependence on fossil fuels for electricity production. Further, it appears that developing these indigenous resources may be possible at lower cost than the present reliance on imported fuels.

This project reviewed the prospects for twenty six renewable and advanced energy technologies. After a first phase of screening, it was found that in the near-term, biomass, municipal solid waste, hydro, wind and landfill gas were the most promising options. Each of these technologies was assessed, typical projects characterized, and their economics evaluated. The summary conclusions of these assessments are provided here, in order of the most promising resources to least.

- **Hydro** – Out of over 40 options, six promising hydro projects were identified, and all seem very economical except for, perhaps, the Upper Lihue upgrade project. The lowest cost projects are the new 4 MW Wainiha and 6.6 MW Wailua developments, at levelized costs of \$58.40/MWh and \$60.40/MWh (2009\$), respectively. However, hydro development does have challenges on Kauai. The last new utility scale hydropower plant on Kauai, Waimea Mauka, was constructed a half century ago. The reasons for this are varied, and highlight the importance of careful project selection, a measured development strategy, and a collaborative development approach involving agricultural/industrial partners, environmental advocates, and the greater island community as a whole. The most important next steps for hydro are discussions with site owners, followed by additional site investigation and feasibility analysis.
- **Wind** – Wind resources on Kauai are good and distributed throughout the island. Theoretically, wind could meet all of Kauai's electrical energy needs if a means could be found to “firm-up” the resource with energy storage or other technologies. This study characterized seven wind sites in Kauai. The projects ranged from developments on relatively flat land with moderate wind speeds but easy site access, to exposed ridgeline developments with higher wind speeds but more difficult construction. The life-cycle economic analysis showed that these attributes roughly counteract each other. With the exception of the smaller 2 MW Kokee project, the 6.6 MW wind projects were close in levelized cost, ranging from \$64/MWh to \$73/MWh. No wind

site stands out as being vastly superior to others, which gives KIUC good flexibility (and negotiation position) in siting the first projects in the location deemed most suitable. Recommended next steps for wind development are preliminary siting based on discussions with land owners and detailed meteorological data collection at likely sites to establish wind speeds at turbine hub heights.

- **Municipal Solid Waste** – Municipal solid waste combustion may be a viable option for Kauai as part an integrated approach to island waste management. However, the economics of MSW strongly depend on the tipping fee received for waste disposal. This study found that at a tipping fee of \$90/ton, a 7.3 MW, 300 ton per day waste to energy plant would produce power for a lower levelized cost than any of the other renewable energy options modeled: \$20/MWh. However, economics are very sensitive to this tipping fee. At \$56/ton (the current landfill gate fee) the levelized cost was estimated to be \$108/MWh. Although this is still lower than KIUC's current avoided cost, it is not as competitive as the other renewable energy options. If KIUC is interested in exploring waste to energy further, it should discuss possible options with the County. The current landfill is running out of capacity, and new landfill capacity will need to be developed. This new landfill capacity will likely be developed at an all-in cost near the upper range of the tipping fees modeled in this study.
- **Landfill Gas** – There is currently only one viable landfill gas project on Kauai, located at the Kekaha landfill. Black & Veatch estimated that an 800 kW project using reciprocating engines could be developed after landfill closure in 2009. At \$99/MWh, the levelized cost of the landfill gas project is competitive with KIUC's current avoided costs, but higher cost than several of the other project options. The project is also considered lower priority for KIUC due to the limited resource potential of LFG on the island and the relatively small project size.
- **Biomass** – Of the project options characterized in detail for this study, biomass has the most unfavorable economics. As the study progressed from the generic technology screening in Phase 1 to the detailed project characterizations in Phase 2, the estimated costs for biomass increased outside of initial expectations. The Phase 2 investigation found that the levelized cost of supplying power from a biomass fueled power station ranged from \$180/MWh to \$205/MWh, depending on the fuel cost. Biomass is hurt by KIUC's lack of need for baseload capacity. However, biomass, especially

derived from locally grown energy crops, does have several advantages over most other renewable energy options: (1) large amounts of baseload power could be produced from the available resource base, (2) growing and harvesting local energy crops would provide a large stimulus for Kauai's agricultural economy and help stem the loss of jobs in the sugar industry and (3) biomass crops for power may be synergistic with crops grown for ethanol fuel production. Based on these factors, it is recommended that biomass be reexamined in more detail when KIUC has greater need for capacity resources in the future.

One of the most tangible benefits of renewable energy to KIUC is lowering the exposure to rising and volatile energy prices. As a final analysis, Black & Veatch compared the levelized cost of renewable energy against KIUC's short-term avoided costs, Schedule Q. A relationship was derived showing the variation in Schedule Q rates versus cost of oil.<sup>1</sup> Figure 1-7 shows a comparison of the cost to generate power from each of the renewable projects analyzed in Phase 2 versus KIUC Schedule Q rates. While Schedule Q rates fluctuate with oil prices, renewable energy costs are constant. The figure shows at what oil price points renewable energy is less or more expensive than diesel engine power generation. At an oil price of about \$55/bbl, landfill gas, wind, hydro, and municipal solid waste combustion are all less expensive than Schedule Q rates. However, over the range of oil prices examined for this analysis, biomass combustion is always more expensive with a lower bound of about \$80/MWh. The average price for diesel oil over the past four years is approximately \$45/bbl. At this price point, hydro, wind, and municipal solid waste combustion with mid to high tipping fees are less expensive than KIUC's Schedule Q rates.

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<sup>1</sup> Personal communication from Jeff Deren, KIUC, November 23, 2004.

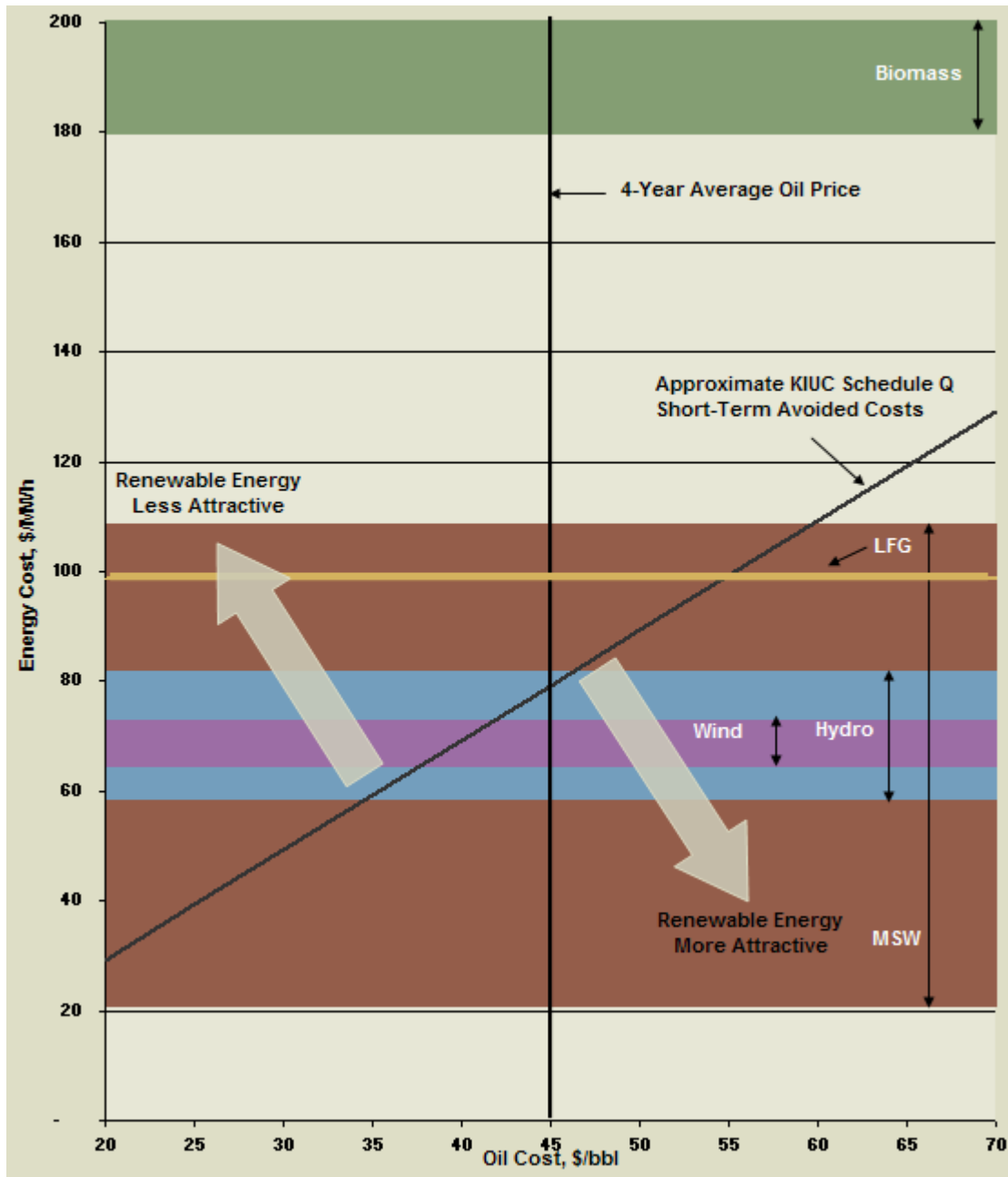


Figure 1-7. Break-Even Cost Analysis for Renewable vs. KIUC's Short Term Avoided Costs.