

## 4.0 Renewable Energy Technology Screening

This section discusses the technology screening methodology that has been used to evaluate, rank and select Kauai renewable energy resources for further investigation. This section discusses the objective of the methodology, the scoring criteria comprising it, the guidelines for application of the scoring criteria, and the results of the screening process.

### 4.1 Objective

The objective of the technology screening methodology is to screen and rank technologies for further evaluation. The methodology considers numerous factors affecting project viability including the cost of energy, resource availability, technology maturity, and environmental and socioeconomic impacts. The combination of scores from these and other areas should provide a preliminary indication of the overall viability of potential resources as KIUC investments.

The assessment methodology must be easily applied, yet meaningful. It also must be objective, consistent, and transparent to outside organizations. To meet these goals, Black & Veatch has developed a set of weighted criteria to evaluate and compare projects.

### 4.2 Screening Criteria

The assessment methodology employs a set of seven criteria. The criteria are given different weights such that 100 total points are possible when the methodology is applied to a given technology. Criteria are specific and measurable to ensure consistent evaluation and quantitative comparison of the final technology scores. The seven criteria are summarized below:

- **Cost of energy** – Assesses the economic competitiveness of the resource. The evaluation is performed based on the levelized busbar cost of generation, which measures the total life-cycle cost of a technology considering capital cost, operating and maintenance cost, capacity factor, and fuel cost (if applicable). Differentiation between various products (firm, as-available, peaking, dispatchable) is assessed in the “Fit to KIUC needs” category.
- **Kauai resource potential** – Indicates the general developable potential of the renewable energy resource in Kauai. There are many methods to determine the technical potential of a particular resource, and literature estimates range considerably. In addition, advancements in technology over time can also

affect estimates of technical potential. For this reason, this evaluation is somewhat subjective and must consider multiple factors.

- **Fit to KIUC needs** – Assesses the fit of the technology to the resource supply needs of KIUC. This criterion considers the scale of the technology, typical generation profile, firm vs. as-available, etc. In the near term, KIUC has sufficient capacity to meet its operating reserve requirements, so firm capacity resources are not preferred.
- **Technology maturity** – Assesses the development status of the technology (commercial, demonstration, R&D, etc.) and the level of technical risk associated with its implementation. Technologies with lower technical risk are given higher scores.
- **Environmental impact** – Assesses the overall environmental impact of the technology. Although renewable energy sources are generally cleaner than fossil fuel power plants, some differentiation can be made among technologies.
- **Socioeconomic impact** – Assesses the overall socioeconomic impact of the technology. Includes factors such as increase in local employment, development of local resources, capacity building, and safety and health impacts.
- **Incentives/Barriers** – Indicates the degree of incentives offered for the renewable resource and barriers against the development of the renewable resource. Incentives may include federal/state subsidies or ancillary benefits of the project, such as addressing solid waste disposal problems. Barriers may include public opposition and other impacts that would raise concerns about the development of the renewable resource.

The weighting factors for the criteria are provided in Table 4-1. 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. Table 4-1 also shows whether criteria also identify a fatal flaw, such as lack of a resource on the island. Finally, some of the scores will change over time as a technology matures or KIUC's needs change in the future. For this reason screening of technologies is done for the next 3, 5, 10 and 20 years.

<b>Table 4-1. Screening Criteria.</b>			
<b>Criteria</b>	<b>Weight</b>	<b>Possible Fatal Flaw?*</b>	<b>Time Variant? **</b>
Cost of energy	50		Yes
Kauai resource potential	10	Yes	Yes
Fit to KIUC needs	10	Yes	Yes
Technology maturity	10	Yes	Yes
Environmental impact	7.5		
Socioeconomic impact	7.5		
Incentives / Barriers	5		

Notes:

- \* Indicates that a failing score for these criteria may result in elimination of the technology from further consideration. For example, lack of geothermal resources on the island eliminates this option from further consideration.
- \*\* Indicates that the score may change over time. For example, wave energy technology is currently in the early demonstration phase, but early commercial applications are expected within the next few years.

### 4.3 Screening Methodology Scoring Guidelines

The assessment methodology was applied by assigning a score from 0 to 100 for each criteria and then applying the weighting factors shown in Table 4-1. The weighted scores are summed to provide the overall project score. Each criterion is scored differently, for example the “cost of energy” and “Kauai resource potential” criteria are largely based on quantitative information. For the remainder of the factors, quantitative data is typically not available, and a qualitative score must be assigned based on available information. Black & Veatch has established individual criteria weighting points and scoring methods as shown in Table 4-2.

**Table 4-2. Screening Methodology Scoring Guidelines.**

Criteria	Weight	Scoring Details
Cost of energy	50	100 = levelized busbar cost of 5¢/kWh or less 0 = levelized busbar cost of 25¢/kWh or more Proportionately scored between 5 and 25¢/kWh
Kauai resource potential	10	100 = developable potential of 500 GWh/yr or more 0 = developable potential of 5 GWh/yr or less Proportionately scored between 500 and 5GWh/yr
Fit to KIUC needs	10	100 = resource is of appropriate scale, energy production profile matches KIUC needs, and meets KIUC needs regarding dispatchability, capacity vs. energy, etc. 0 = typical project is too large or small, produces energy at unneeded times, and provides product (such as capacity) of little value. Proportionately scored between two extremes
Technology maturity	10	100 = established commercial technology that has been widely adopted. Technology is offered by multiple competitive vendors and fully warranted. 75 = established technology that has been used in several similar applications 50 = early commercial technology that has been successfully demonstrated 25 = emerging technology in the demonstration phase 10 = technology still in research and development 0 = technology concept
Environmental impact	7.5	Relative to other renewable energy technologies: 100 = substantial environmental benefits leading to a cleaner and more sustainable environment 50 = some environmental benefits (base score) 0 = negative environmental effects
Socioeconomic impact	7.5	Relative to other renewable energy technologies: 100 = substantial socioeconomic benefits enhancing the island's economy, health, and general well-being 50 = some socioeconomic benefits (base score) 0 = negative socioeconomic effects
Incentives/Barriers	5	100 = Significant incentives (e.g., substantial federal subsidy) and no apparent barriers to development. 50 = No significant incentives or barriers 0 = No incentives but substantial obstacles to successful project development

Notes:

- \* Indicates that a failing score for these criteria may result in elimination of the technology from further consideration. For example, lack of geothermal resources on the island eliminates this option from further consideration.
- \*\* Indicates that the score may change over time. For example, wave energy technology is currently in the early demonstration phase, but early commercial applications are expected within the next few years.

## 4.4 Screening Results

The screening methodology was applied to each of the renewable energy technologies for their potential to contribute to the renewable energy supply within the next 3, 5, 10, and 20 years. The results for each of the criteria are summarized below.

#### 4.4.1 Cost of Energy

The levelized cost of energy is a measure of the total life-cycle cost of a project or technology to generate power. Because the cost of developing a facility can vary considerably, even with modular technologies such as solar photovoltaic or wind energy, a range of project costs and performance assumptions were used to develop levelized cost estimates for each renewable energy technology. The multi-fuel generation technologies were evaluated separately as a fuel has not yet been selected for each of these technologies and the levelized cost of generation is heavily dependent upon the fuel cost. Black & Veatch used the technology cost and performance assumptions developed in the previous section, which are summarized in Table 4-3 for the three year timeframe. The values shown in the table were chosen as representative of the technology application in Kauai.

Of the renewable energy technologies evaluated, wind power has the lowest capital cost per kW installed at \$1,200-1,600/kW. This has resulted in a 30 percent annual increase in wind installations worldwide over the last five years. System costs have gone down as single turbines have achieved megawatt sizes. In comparison, conventional biomass and geothermal technologies have capital costs in the range of \$2,600-3,900/kW and \$3,300-5,200/kW, respectively. The high cost of biomass plants has to do with their relatively small size, extensive fuel and ash handling requirements, and the need for a robust plant design to handle the variability in the fuel quality. Geothermal power plant costs and complexity are highly dependent on the temperature of the geothermal resource, its proximity to the surface and the quality of the brine to be handled. Due to their extensive material handling and emissions control requirements, waste to energy technologies have a substantially higher capital cost than biomass plants, ranging from \$6,500 to 11,700/kW. The small size of a potential waste to energy plant in Kauai also increases its relative costs due to economies of scale. Hydroelectric power plants have a wide range of capital costs from \$1,700–5,700/kW. Given the turbine technology used for power production is quite mature and costs are low, the civil work that needs to be done to build dams and penstocks tends to be the driving factor behind the capital cost of these systems. Photovoltaic systems are by far the most expensive renewable energy technology with capital costs from \$8,300–10,500/kW and a capacity factor of only 20 percent. These systems are currently too expensive to be applied competitively at utility scale. However, they have found a niche in the remote power supply market for rural electrification, water supply, and other applications.

Table 4-3. Renewable Technologies Performance and Cost Summary, Three Year Timeframe.<sup>a</sup>

	Net Plant Capacity, MW	Net Plant Heat Rate, Btu/kWh	Capacity Factor	Capital Cost, \$/kW	Fixed O&M, \$/kW-yr	Variable O&M, \$/MWh	Fuel Cost, \$/MBtu	Levelized Cost, \$/MWh
Direct Biomass	30	14,500	80	2,600-3,900	78	10	3	114-127
Cofired Biomass	1-50	9,000-12,000	70	100-800	7-26		3	39-64
Anaerobic Digestion	0.085		80	3,000-4,900		20	0	57-77
Landfill Gas	0.2-15		80	1,700-3,500		20	0	44-63
Ethanol	b	8,000	65	b	b	b	19-23	206-249
Biodiesel	b	9,000	65	b	b	b	15-19	183-232
MSW Mass Burn	7	17,500	70	6,500-9,100	260-455	20-33	-5 <sup>c</sup>	41-132
RDF	7	19,300	70	9,100-11,700	455-715	26-39	-5 <sup>c</sup>	110-215
Plasma Arc	6.6	19,000	70	7,200-9,100	260-455	20-33	-5 <sup>c</sup>	39-122
Hydro	0.5-10		50	1,700-5,700	14-29	3-6		36-109
OTEC (Off-shore)	100		90	3,300-6,500		17-33		53-103
Wave	10		40	4,600-5,900		59-78		173-225
Tidal	18-40		20	3,300-6,800	7-33	1-3		140-305
Solar PV (commercial)	0.050		20	8,300-10,500	26	30		397-563
Solar Thermal (trough)	100		47.5	5,200-6,500		33-39		133-164
Wind (wind farm)	10		35	1,200-1,600	30-35	2-3		44-57
Geothermal	30		80	3,300-5,200	260-390			84-128
IC Engine (spark) <sup>d</sup>	0.001-5	9,700	50	500-1,300		20-33	12	193-223
Comb. Turbine <sup>d</sup>	0.3-10	11,000	50	700-2,000		20-33	12	217-256
Microturbine <sup>d</sup>	0.015-0.06	12,200	50	1,100-2,000		13-26	12	234-266
Fuel Cell <sup>d</sup>	0.1-0.25	7,000-9,500	50	6,000-8,400	650-910	7-13	12	421-589

Notes:

<sup>a</sup> Excludes incentives, subsidies, etc.

<sup>b</sup> Fuel switch Assumed negligible incremental cost for integrating with existing infrastructure.

<sup>c</sup> \$50/ton tipping fee.

<sup>d</sup> Multi-fuel technologies included for relative comparison. Generation cost is strongly linked to fuel cost, assumed \$12/MBtu.

When comparing the levelized cost of energy produced by these systems, hydroelectric power, landfill gas, biomass cofiring, and geothermal energy all currently produce power at rates competitive with bulk power generation (note that geothermal is not viable on the island). Although these resources have high capital costs, low operating costs combined with high operating capacity factors reduce the overall life-cycle costs. Wind power costs are steadily falling and are significantly lower than costs a decade ago due to increases in wind turbine size and efficiency. Costs for other biomass technologies (direct combustion and anaerobic digestion) are higher given the relatively high capital and operating and maintenance cost of the plants. Direct combustion biomass plants are especially sensitive to fuel cost. This screening section assumes a fuel cost of \$3/MBtu, which is higher than most waste biomass fuels (e.g., bagasse) but lower than energy crop fuels. Although waste to energy plants have very high capital costs, high tipping fees can make them economical. The \$50/ton tipping fee assumed for this analysis is conservatively low. Ocean and solar technologies are currently expensive, and will likely be reserved for niche applications until costs drop further. Finally, despite requiring minimal incremental capital or operating costs, fuel substitution with ethanol or biodiesel will not be competitive until the costs of these fuels drop below that of their fossil fuel counterparts or adequate financial incentives are offered to cover the higher cost.

Continued improvements will result in improvements in efficiency, capital cost, and operating and maintenance cost for several of the technologies. The technology areas where the levelized cost of power production should come down in the future are wind, photovoltaics, solar thermal, ocean, plasma arc, microturbines, fuel cells, and biofuels. Large improvements are expected for solar photovoltaics and wave energy, with relatively modest improvements in other technologies. These improvements have been included in the forecasts for technology costs beyond the three year timeframe.

The technology specific assumptions and the economic assumptions in Table 4-3 were used to calculate the levelized cost of energy. The calculated average cost of energy for each technology for the next 3, 5, 10, and 20 years is shown in Figure 4-1. The range of costs for the three year timeframe is shown in Figure 4-2. The average levelized cost value was used to provide each technology with a score out of 100, with 100 being lower cost (<\$50/MWh), and 0 being higher cost (>\$250/MWh). The results of the cost of energy screening are provided in Table 4-4.

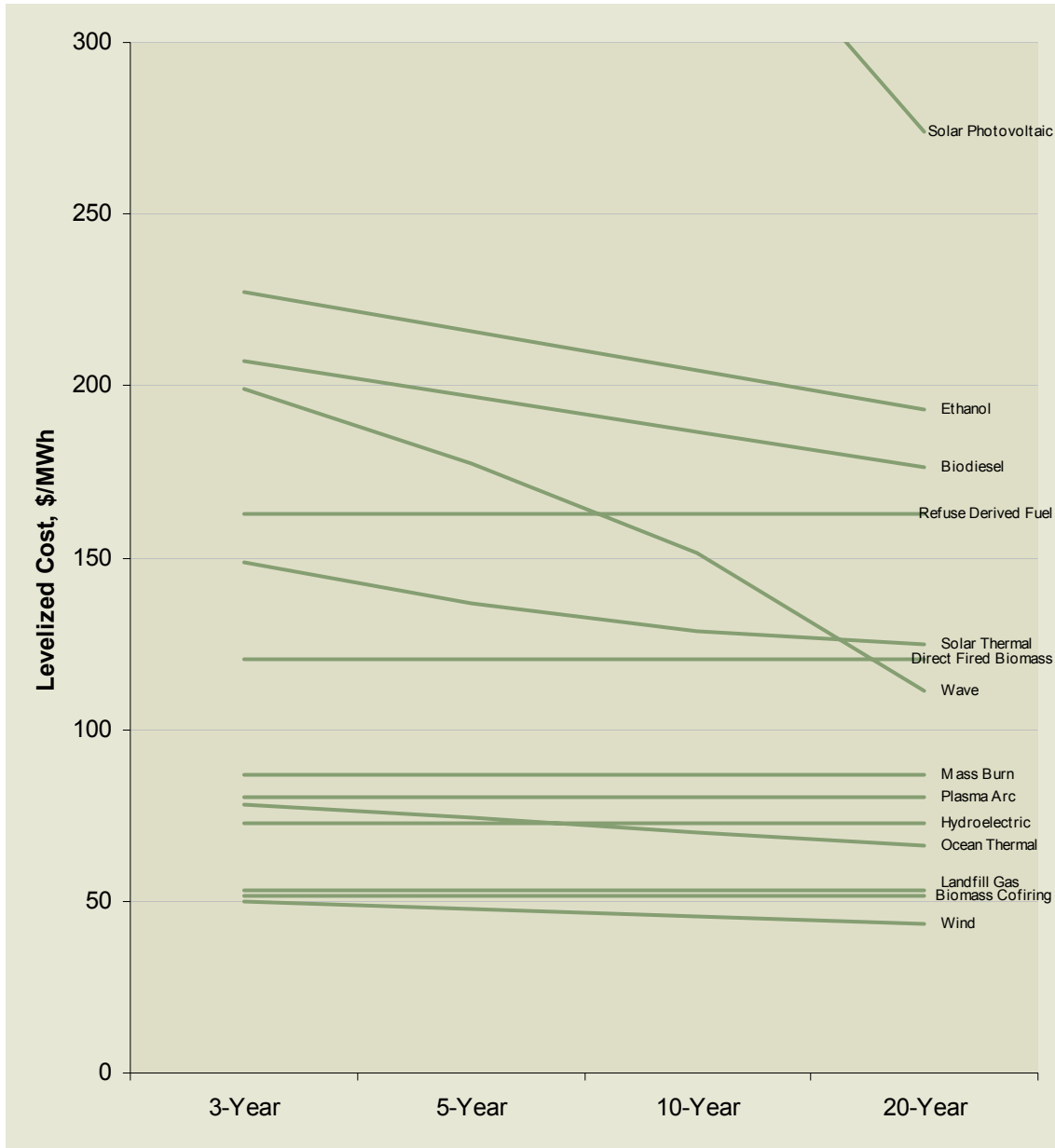


Figure 4-1. Trends in Average Levelized Cost of Energy for Renewable Resources (2005\$).

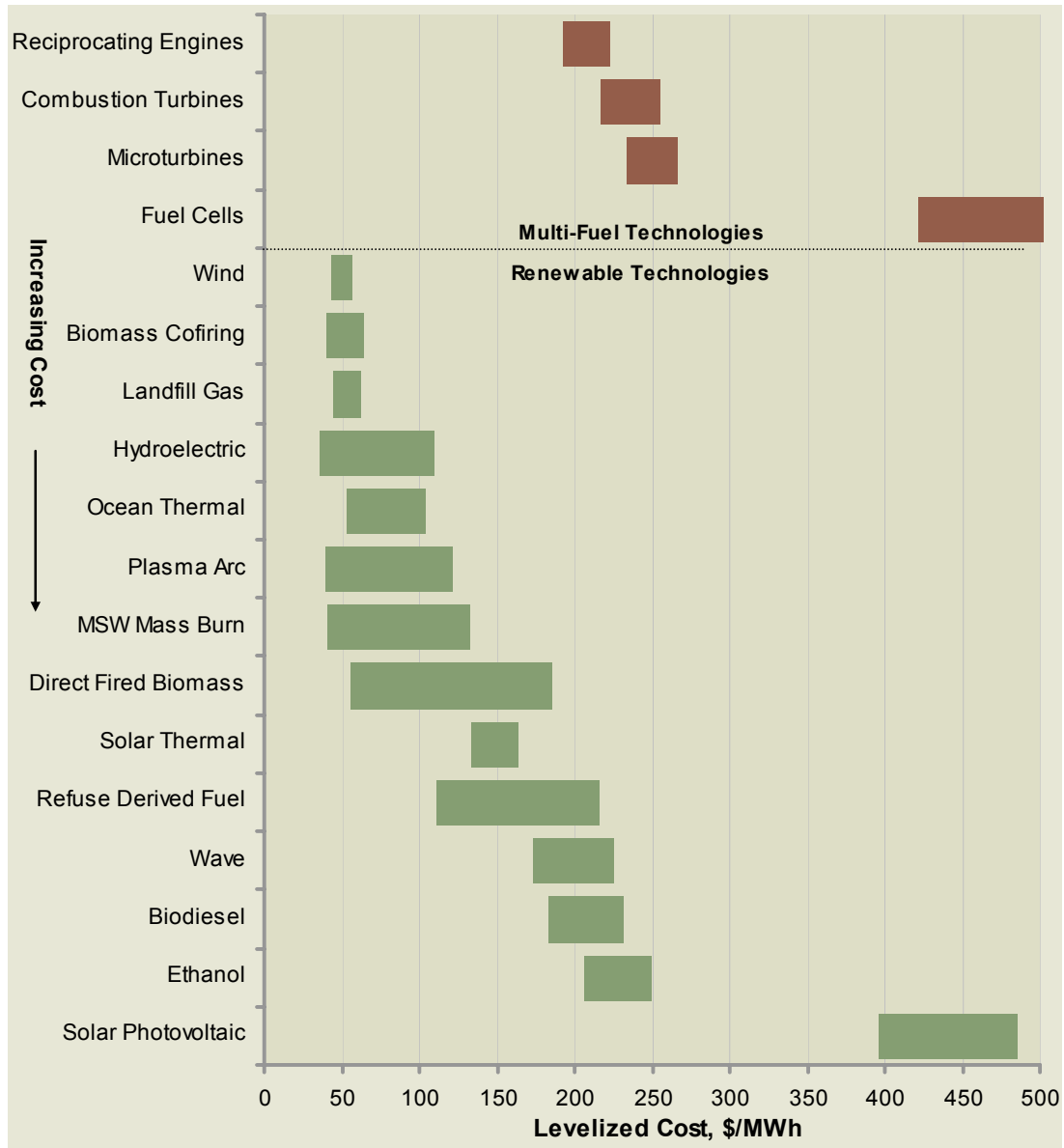


Figure 4-2. Range of Levelized Cost for Renewable Technologies (Three Year Timeframe).

<b>Table 4-4. Cost of Energy Screening Results (Sorted by 3-Year Score).</b>				
<b>Technology</b>	<b>3-Year</b>	<b>5-Year</b>	<b>10-Year</b>	<b>20-Year</b>
Wind	100	100	100	100
Biomass Cofiring	99	99	99	99
Landfill Gas	98	98	98	98
Hydroelectric	89	89	89	89
Ocean Thermal	86	88	90	92
Plasma Arc	85	85	85	85
Mass Burn	82	82	82	82
Direct Fired Biomass	65	65	65	65
Solar Thermal	51	57	61	63
Refuse Derived Fuel	44	44	44	44
Wave	25	36	49	69
Biodiesel	21	27	32	37
Reciprocating Engines	21	21	21	21
Ethanol	11	17	23	28
Combustion Turbines	7	7	7	7
Microturbines	0	1	1	2
Solar Photovoltaic	0	0	0	0
Fuel Cells	0	0	0	0

**4.4.2 Kauai Resource Potential**

The developable potential was estimated for each renewable technology for the next 3, 5, 10 and 20 years. The background to these estimates is documented for each technology in the previous section under the “Kauai Outlook” subsections. The annual electricity generation (GWh/yr) estimates are shown in Figure 4-3.

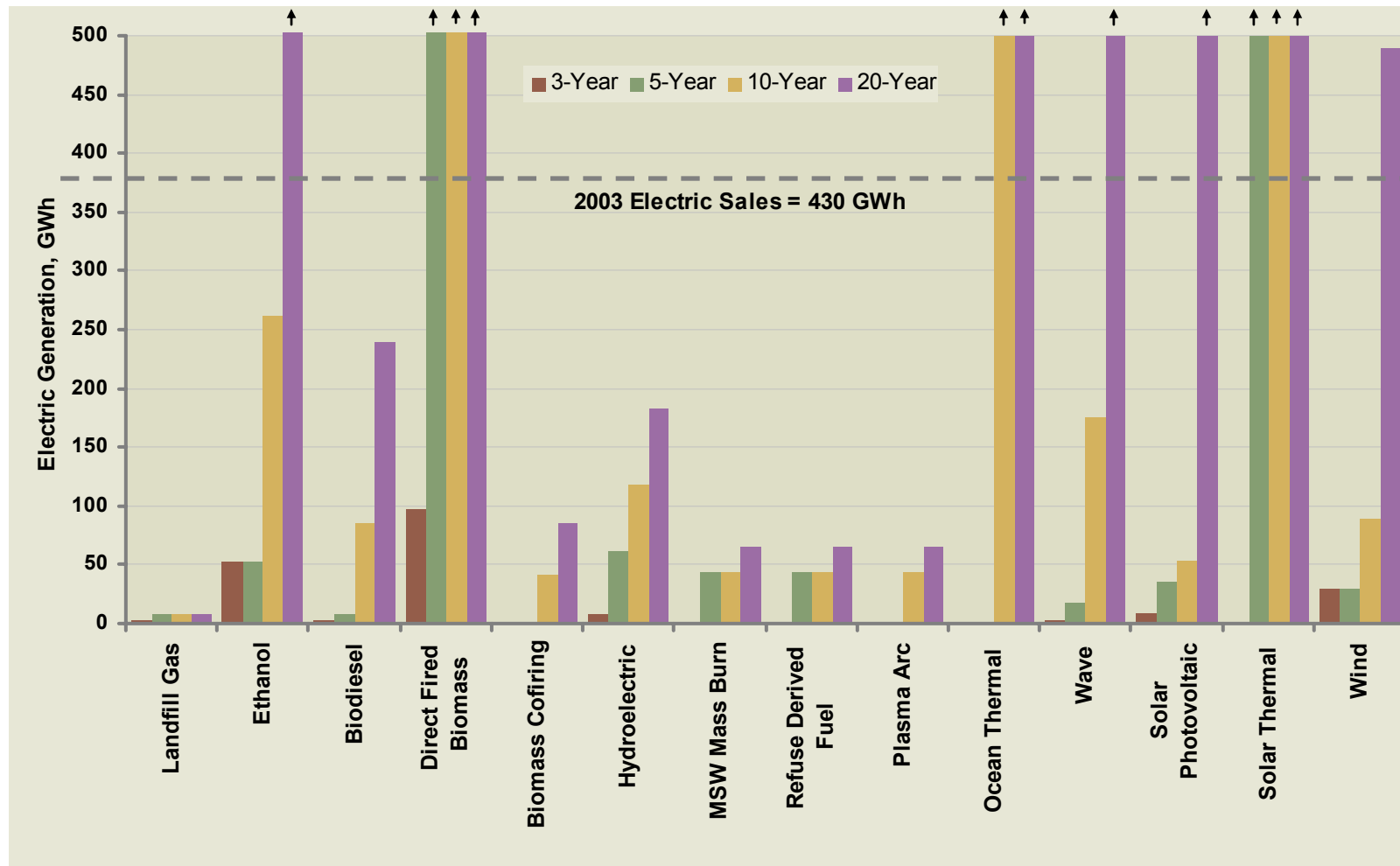


Figure 4-3. Developable Potential of Kauai Renewable Resources (Annual Generation, GWh/yr).

There are several resources that could theoretically meet all of Kauai's electricity needs (energy basis), which totaled about 430 GWh in 2003. However, in the near term (5 years) only direct fired biomass and solar thermal appear able to supply all Kauai's electrical needs. Most of the other technologies are limited by either (1) resource, (2) status of technology development (that is, the industry is not capable of supplying all the necessary equipment in such a short time), and (3) intermittency issues (that is, full scale implementation would require energy storage or other advanced solutions). In the long term, it appears that ethanol, ocean thermal, ocean wave, and solar photovoltaic should also each be able to supply enough electricity to meet the island's needs. Biodiesel, hydroelectric and wind also all have good developable potential. Biomass cofiring, landfill gas, and the waste to energy technologies all have relatively limited potential. Finally, geothermal, anaerobic digestion, and ocean tidal were all determined to have negligible developable resource potential and have been excluded from further analysis.

Resources able to supply in excess of 500 GWh per year were given a score of 100, while resources capable of supplying 5 GWh or less were given a score of 0; the others were scored proportionally in between these extremes. The results of the resource potential screening are provided in Table 4-5.

<b>Table 4-5. Resource Potential Screening Results (Sorted by 3-Year Score).</b>				
<b>Technology</b>	<b>3-Year</b>	<b>5-Year</b>	<b>10-Year</b>	<b>20-Year</b>
Direct Fired Biomass	19	<b>100</b>	<b>100</b>	<b>100</b>
Ethanol	10	10	52	<b>100</b>
Wind	5	5	17	98
Solar Photovoltaic	1	6	10	<b>100</b>
Hydroelectric	1	11	23	36
Solar Thermal	0	<b>100</b>	<b>100</b>	<b>100</b>
Mass Burn	0	8	8	12
Refuse Derived Fuel	0	8	8	12
Wave	0	3	34	<b>100</b>
Biodiesel	0	0.4	16	47
Landfill Gas	0	0.4	0.4	0.4
Ocean Thermal	0	0	<b>100</b>	<b>100</b>
Plasma Arc	0	0	8	12
Biomass Cofiring	0	0	7	16
Notes:				
* Negligible potential: geothermal, ocean tidal, anaerobic digestion.				
** Multi-fuel generation technologies not shown (assumed 100 potential score).				

Based on the 20-year resource potential estimates, calculations were made to demonstrate what percent of Kauai's annual energy demand could be met by the various resources. This is a theoretical calculation; it would not be advisable to rely on any single resource. Nevertheless, it again shows that there are several resources capable of supplying all of the island's energy needs. In addition, the theoretical barrels of No. 2 oil displaced has also been calculated as shown in Table 4-6.

**Table 4-6. Resource Potential Comparisons.**

<b>Technology</b>	<b>20-Year Resource Potential GWh/yr</b>	<b>Theoretical Potential Percent of 2023 Electrical Energy Supply *</b>	<b>Barrels of Oil (No. 2) Displaced, bbl/yr **</b>
Landfill Gas	7	2%	11,367
Ethanol	525	>100%	>740,000
Biodiesel	239	52%	388,118
Direct Fired Biomass	714	>100%	>740,000
Biomass Cofiring	84.1	18%	136,572
Hydroelectric	183	40%	297,178
Mass Burn	65.7	14%	106,692
Refuse Derived Fuel	65.7	14%	106,692
Plasma Arc	65.7	14%	106,692
Ocean Thermal	>500	>100%	>740,000
Wave	>500	>100%	>740,000
Solar Photovoltaic	>500	>100%	>740,000
Solar Thermal	>500	>100%	>740,000
Wind	490	>100%	>740,000

Notes:

\* Assumes 2 percent load growth from 2003 value of 430 GWh/yr. 2023 value would be 456 GWh/yr.

\*\* Based on 2023 electrical generation forecast and average thermal system heat rate of 9460 Btu/kWh.

**4.4.3 Fit to KIUC Needs**

The Fit to KIUC Needs criterion is a measure of the applicability and suitability of a technology to the KIUC system for each of the timeframes. This criterion encompasses the technology generation profile, scale of a typical project, and type of product (firm versus as-available). For this study it was assumed that firm and peaking capacity are the preferred generation products in the long-term (10 to 20 years), but that as-available resources (such as solar, wind, and hydro) are preferred in the 3 to 5-year timeframe. Alternative fuels (biodiesel and ethanol) were given the highest score, as these could be readily incorporated into the existing KIUC generation infrastructure as appropriate and cost effective. Ocean thermal energy conversion was given the lowest score in the near term because it is a capacity resource and plants would need to be very large to be economical. Table 4-7 shows the results of the evaluation.

**Table 4-7. Fit to KIUC Needs Screening Results (Sorted by 3-Year Score).**

<b>Technology</b>	<b>3-Year</b>	<b>5-Year</b>	<b>10-Year</b>	<b>20-Year</b>
Ethanol	100	100	100	100
Biodiesel	100	100	100	100
Solar Photovoltaic	85	85	85	85
Landfill Gas	75	75	100	100
Solar Thermal	75	75	75	75
Hydroelectric	75	75	50	50
Wave	75	75	50	50
Wind	75	75	50	50
Direct Fired Biomass	50	50	100	100
Mass Burn	50	50	100	100
Refuse Derived Fuel	50	50	100	100
Plasma Arc	50	50	100	100
Reciprocating Engines	50	50	100	100
Combustion Turbines	50	50	100	100
Microturbines	50	50	100	100
Fuel Cells	50	50	100	100
Biomass Cofiring	0	0	50	50
Ocean Thermal	0	0	25	25

#### 4.4.4 Technology Maturity

The level of technology maturity is a measure of the relative development of a technology. In general, the less developed a specific technology, the higher the risk that a project will fail for technical, commercial, or other reasons. For example, a technology in research and development (e.g., plasma arc gasification) is much more likely to fail than a technology that is supported by several vendors and has been applied in numerous applications around the world (e.g., wind turbines).

The level of maturity of each technology was rated for the 3, 5, 10, and 20 year periods. Of the commercially available renewable energy technologies, hydroelectric power has the largest amount of installed capacity in the world today. It is followed by biomass direct combustion and then wind, geothermal, and solar energy. The following technologies are currently considered to be fully commercial and could make a contribution to the energy supply in Kauai in the near term (if sufficient resources are available):

- |  |  |
|--|--|
| <ul style="list-style-type: none"><li>• Anaerobic digestion</li><li>• Biomass Cofiring</li><li>• Landfill gas</li><li>• Biodiesel</li><li>• Direct fired biomass</li><li>• Hydroelectric</li><li>• Waste-to-energy mass burn</li></ul> | <ul style="list-style-type: none"><li>• Refuse derived fuel</li><li>• Solar photovoltaic</li><li>• Wind</li><li>• Geothermal</li><li>• Reciprocating engines</li><li>• Combustion turbines</li></ul> |
|--|--|

Although advancements in these technologies will occur over the next 20 years, particularly solar photovoltaic technology, these technologies are fully capable of utility deployment in the near term.

The progression towards commercialization of the developmental technologies was estimated from Black & Veatch experience. Table 4-8 presents the expected development of technologies that are not yet fully commercial.

<b>Table 4-8. Technology Maturity Screening Results.</b>				
<b>Technology</b>	<b>3-Year</b>	<b>5-Year</b>	<b>10-Year</b>	<b>20-Year</b>
Ethanol	50	75	<b>100</b>	<b>100</b>
Microturbines	50	75	<b>100</b>	<b>100</b>
Solar Thermal	50	50	75	<b>100</b>
Wave	25	50	75	<b>100</b>
Fuel Cells	25	50	75	<b>100</b>
Plasma Arc	25	25	50	75
Ocean Thermal	25	25	50	75

Ethanol production techniques have been successfully demonstrated and are currently being used around the world. However, experience with ethanol for power production is limited. With continued application over the next ten years, it is expected that power production from ethanol will be a fully commercial technology.

Plasma arc gasification has been demonstrated in several applications; however, there is still significant ongoing R&D into this technology. It is expected that within 10 years plasma arc gasification will be in the early commercial stages and will reach near fully commercial status within 20 years if additional facilities are built.

OTEC and WECS have been successfully demonstrated in several demonstration projects, however, there is still significant ongoing R&D activities. There are some plans for further demonstration of these technologies in Europe and Asia and it is expected that within 10 years the technology will be in the early commercial stages, and will reach near commercial status within 20 years if additional facilities are built.

Ocean tidal energy conversion has been successfully demonstrated and applied to large-scale commercial applications. However, there is still a limited number of operating facilities in the world, and there are no known major projects planned in the near future. Little additional development of the technology is planned.

Solar thermal energy technologies have been successfully demonstrated and there is currently over 350 MW of operating solar trough capacity in California. However, there have not been any plants built in the past 15 years. In the next 10 to 20 years solar thermal technologies could become fully commercial if additional facilities are built.

Microturbines are in the early stages of commercialization. The technology has been successfully demonstrated in applications with a wide variety of fuels including natural gas, landfill gas, digester gas, and other hydrocarbon fuels. With continued development and the emergence of a competitive vendor network, this technology is expected to reach fully commercial status in 10 years.

The four major fuel cell technologies are currently in the R&D and demonstration stages. Fuel cell vendors anticipate that early commercial products will be available within the next 5 years, and due to the high levels of government and private funding for fuel cell development, it is anticipated that full commercialization will be achieved within 20 years.

**4.4.5 Environmental Impact**

Renewable energy technologies were differentiated by their environmental impact relative to other renewable energy technologies, and the degree to which the technology contributed to sustainable use of natural resources in Kauai. A score of 50 is considered to be the baseline score for this criterion, with resources possessing additional positive or negative impacts receiving either higher or lower scores, respectively. Table 4-9 shows the results of the environmental impact screening.

<b>Table 4-9. Environmental and Socioeconomic Impact Screening Results (Sorted by Combined Score).</b>		
<b>Technology</b>	<b>Environmental</b>	<b>Socioeconomic</b>
Ethanol	50	100
Biodiesel	50	100
Direct Fired Biomass	50	100
Plasma Arc	60	75
Solar Photovoltaic	85	50
Microturbines	75	60
Fuel Cells	75	60
Biomass Cofiring	50	75
Refuse Derived Fuel	50	75
Solar Thermal	75	50
Wind	75	50
Landfill Gas	50	50
Hydroelectric	50	50
Mass Burn	25	75
Ocean Thermal	25	75
Wave	50	50
Reciprocating Engines	50	50
Combustion Turbines	50	50

The majority of technologies received the baseline score of 50. These technologies, while relatively environmentally benign, do not possess outstanding environmental benefits or detriments to Kauai.

Mass burn, ocean thermal, and ocean tidal energy received lower scores because of potential adverse environmental impacts. There is concern about the potential for hazardous air emissions from MSW mass burn facilities. OTEC received a lower score because of outstanding questions about possible impacts to ocean life and ecosystems from possible changes to thermal, salinity, and nutrient gradients.

The plasma arc gasifier technology received a higher environmental impact score than the other waste to energy technologies because of superior solid waste disposal. Hazardous inorganic constituents in the waste are vitrified to form a glassy slag that is safer to dispose of than raw MSW or ash from traditional MSW mass burn facilities.

Solar photovoltaic received the highest environmental impact rating because there are minimal environmental impacts from solar photovoltaic generation and solar panels can be placed on existing structures (no new site development).

Solar thermal received a rating of 75 because there are no air emissions associated with this technology. However, development of a significant land area, and significant amounts of water for cooling would be required.

Wind received a score of 75 because while there are no air or wastewater emissions associated with this technology, there are potential impacts to avian populations and a significant amount of land is required for development of this resource.

Microturbines and fuel cells have the potential to produce lower emissions and operate at higher efficiencies than reciprocating engines or combustion turbines, thus these technologies received a better environmental impact score.

#### **4.4.6 Socioeconomic Impact**

Each renewable energy technology was evaluated based on the socioeconomic benefits enhancing the island's economy, health, and general well being from the development of the technology. Discriminating factors for this criterion included job creation, solving existing socioeconomic problems on the island, and transfer of knowledge to the island. Table 4-9 presents the results of the socioeconomic impact screening.

A score of 50 is considered to be the baseline for this category, with technologies that contribute additional benefits receiving a higher score. None of the technologies received a score lower than 50, because none of the technologies were deemed to produce negative socioeconomic impacts relative to conventional technologies.

Ethanol, biodiesel, and biomass production received scores of 100 because of the large benefits associated with the creation of a biomass fuel supply infrastructure which would generate a large number of jobs and capital investment in the local economy.

Waste to energy technologies including mass burn, refuse derived fuel, and plasma arc gasification, received socioeconomic impact scores of 75 due to the benefit of improved solid waste disposal with these technologies.

Microturbines and fuel cells received scores of 60 because the benefits associated with development of advanced technology on the island including knowledge transfer to local personnel and development of high tech jobs.

**4.4.7 Incentives / Barriers**

The degree of incentives or barriers to development is a measure of the difficulty of developing a particular resource. The existence of tax incentives, grant funding, or good public perception can aid in the development of a renewable resource. Conversely, a lack of incentives, or poor public perception, can prevent a project from being developed. The incentives or barriers to development of each technology were scored based on the criteria provided in Table 4-10.

<b>Table 4-10. Incentives / Barriers Scoring Criteria.</b>			
<b>Points</b>	<b>Incentives</b>	<b>Points</b>	<b>Barriers</b>
2	Availability of credits, grants, subsidies, etc.	-1	Potential for negative public health impacts
2	Complementary to existing industry	-2	Not good fit with industry
3	Good public acceptance	-3	Negative public perception
2	Addresses waste disposal issues	-2	Visual impacts
2	Easily actionable	-2	Lack of supporting industry
1	Replicability / modularity	-2	Hurricane susceptible
2	Experienced O&M staff already on island	-3	Requires development of host facility

Each technology received positive and negative points for the incentives and barriers, respectively. The points from each category were then added together, multiplied by five and added to 50 to produce the final score. Table 4-11 provides the results of the Incentives / Barriers screening analysis.

**Table 4-11. Incentives / Barriers Screening Results**

	Incentives							Barriers							Score
	Credits, Subsidies, etc.	Complementary to Existing Industry	Good Public Acceptance	Addresses Waste Disposal Issues	Easily Actionable	Replicability / Modularity	Experienced O&M Staff Already on Island	Possible Negative Public Health Impacts	Not Good Fit Existing Industry	Negative Public Perception	Possible Negative Visual Impacts	Lack of Supporting Industry	Hurricane Sensitive	Requires Development of Host Power Facility	
Points	2	2	3	2	2	1	2	-1	-2	-3	-2	-2	-2	-3	
Biodiesel	■	■	■		■	■									100
Solar Photovoltaic	■		■		■	■									90
Landfill Gas			■		■		■								85
Refuse Derived Fuel			■	■			■								85
Direct Fired Biomass	■	■	■				■			■					80
Fuel Cells	■	■	■			■						■			80
Anaerobic Digestion	■		■	■					■						75
Ethanol	■	■	■								■				75
Reciprocating Engines					■	■	■								75
Combustion Turbines					■	■	■								75
Microturbines			■		■	■						■			70
Plasma Arc			■	■								■			65
Solar Thermal	■		■									■			65
Geothermal	■		■									■			65
Hydroelectric						■	■			■					50
Wind	■		■			■					■	■	■		50
Biomass Cofiring		■					■			■				■	40
Mass Burn				■				■		■					40
Ocean Thermal										■	■		■		15
Ocean Tidal										■	■		■		15
Wave						■				■	■	■	■		10

This analysis concluded that landfill gas, biodiesel, direct fired biomass, refuse derived fuel, solar photovoltaics, and fuel cells have the greatest level of incentives and fewest barriers to development on Kauai. Although the incentives and barriers differed between these technologies, some similarities exist that produced high scores. All technologies are deemed to have good public acceptance, and credits or subsidies are generally available for all but landfill gas and refuse derived fuel. In addition, no significant barriers were identified to the development of any of these technologies.

Technologies with substantial barriers to development include all the ocean energy technologies, MSW mass burn, and biomass cofiring. The primary barrier to biomass cofiring is that it would require development of a new host coal facility.

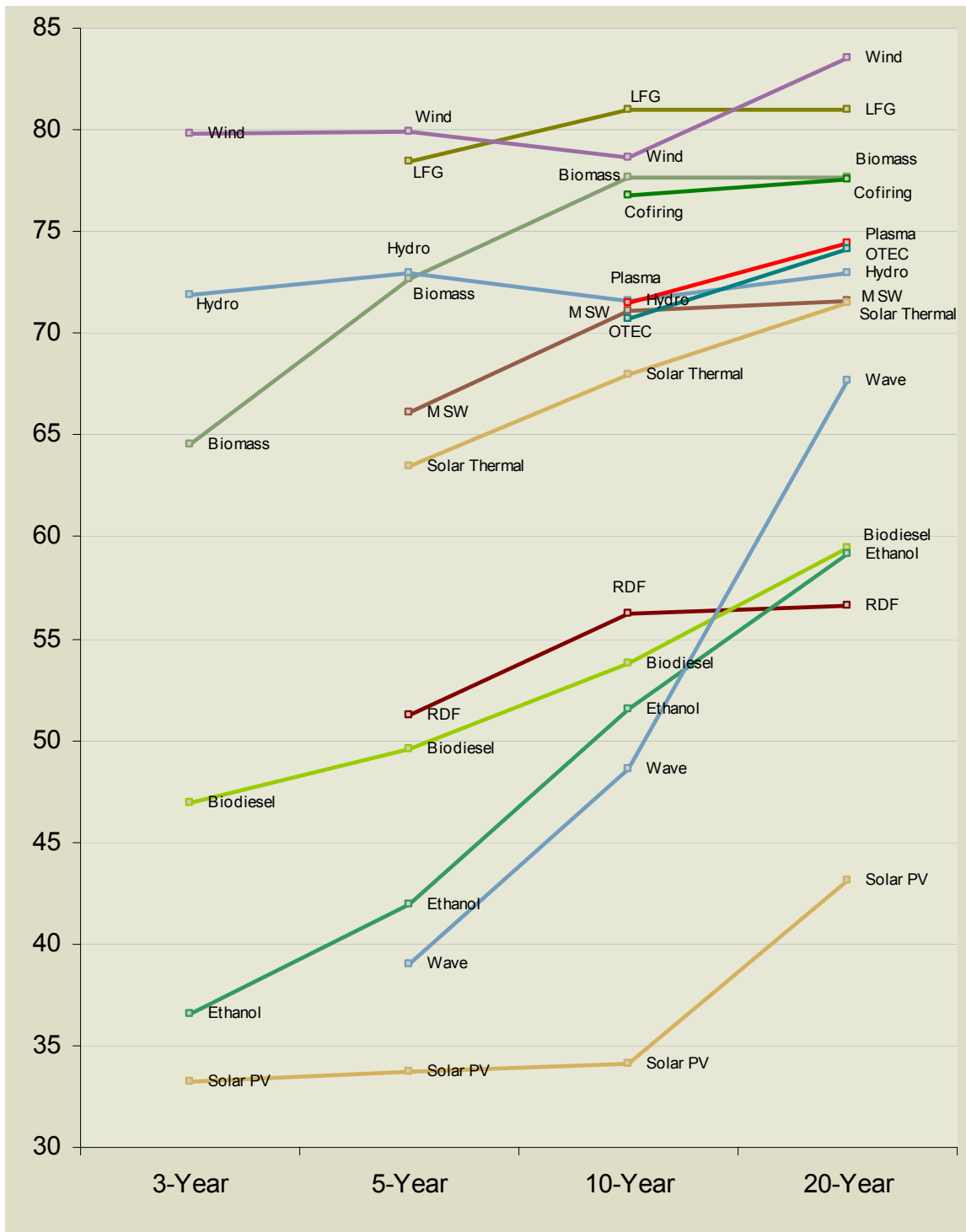
Interestingly, wind and hydro received the same score: 50 out of 100. There is an even mix of both incentives and barriers to developing these types of projects.

**4.4.8 Summary Conclusions**

The scores for each of the criteria were summed together of 3, 5, 10 and 20 year timeframes. The results are shown in Table 4-12 for each of the periods. This information is also charted in Figure 4-4.

<b>Table 4-12. Technology Screening Results (Sorted by Year 10).</b>				
<b>Technology</b>	<b>3-Year</b>	<b>5-Year</b>	<b>10-Year</b>	<b>20-Year</b>
Landfill Gas	*	78	81	81
Wind	80	80	79	87
Direct Biomass	65	73	78	78
Biomass Cofiring	*	*	77	78
Hydroelectric	72	73	72	73
Plasma Arc	*	*	72	74
MSW Mass Burn	*	66	71	72
Ocean Thermal	*	*	71	74
Solar Thermal	*	63	68	71
Refuse Derived Fuel	*	51	56	57
Biodiesel	47	50	54	59
Reciprocating Engine	47	47	52	52
Ethanol	37	42	52	59
Wave	*	39	49	68
Combustion Turbines	40	40	45	45
Microturbines	34	36	44	45
Fuel Cells	32	34	42	44
Solar Photovoltaic	33	34	34	43

\* No developable potential in this timeframe.



**Figure 4-4. Change in Technology Screening Scores by Timeframe.**

An example of the breakdown of the scores by criteria is shown for the ten-year timeframe in Figure 4-5.

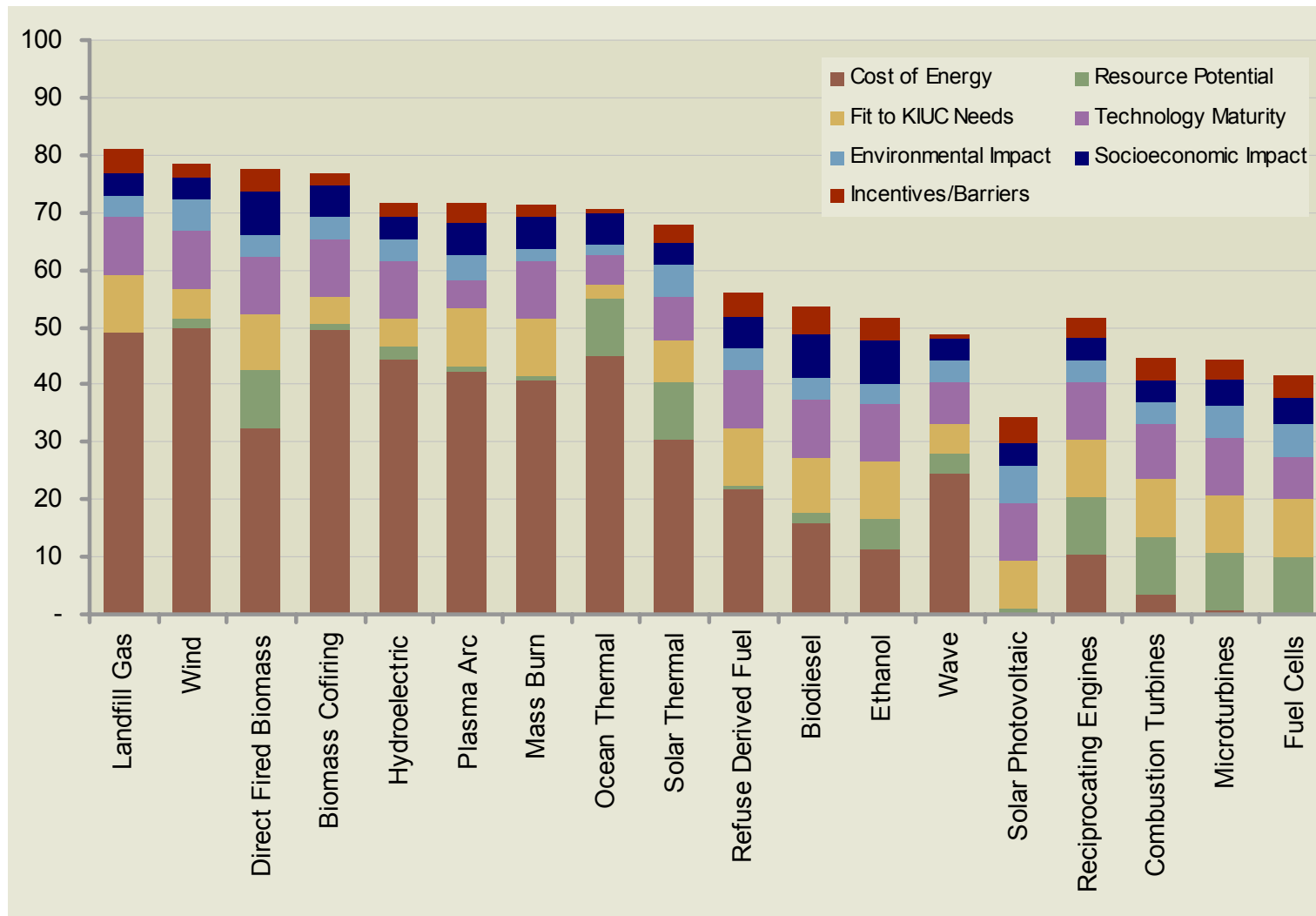


Figure 4-5. Screening Score Breakdown for 10-Year Timeframe.

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. Wave energy and biofuels are examples of technologies that start with relatively modest scores, but increase rapidly during the evaluation period. The small decline for wind and hydro between year 5 and year 10 is due to a change in the Fit to KIUC score that favors capacity resources in the long term.

Although cost of energy is by far the largest contributor to the overall score, a poor score in this category does not necessarily imply an overall low score. A good example is direct fired biomass, which makes up for its poor economics with high scores in resource potential, socioeconomic impacts, fit to KIUC needs, and technology maturity. On the other hand, biodiesel, ethanol, and solar photovoltaics are unable to overcome their poor economics with ancillary benefits.

Based on the results of the scoring process and the information detailed elsewhere in this report, the following observations are made about the technologies:

- **Landfill Gas** – Very good all around scores and low cost. However, potential is limited to around 1 MW.
- **Wind** – Very good all around with potentially lowest levelized cost of all technologies evaluated. Implementation of larger projects (>10 MW) will likely require advanced supporting technologies, such as energy storage.
- **Direct Fired Biomass / Biomass Cofiring** – High resource potential and socioeconomic impacts overcome relatively high cost of electricity. A project based on low cost resources (wood waste, bagasse, etc.) will have substantially improved economics. Cofiring of biomass in a new coal plant may also have attractive economics, *if* a coal plant can be built.
- **Hydroelectric** – The potential for hydroelectric is strong due to good resource potential and generally attractive economics. However, more than any other resource, hydro costs are highly site specific, and it is difficult to generalize about the competitiveness of the resource against the other renewables. Detailed information is needed on specific project opportunities to further assess the prospects for hydro on Kauai.
- **Waste to Energy** (Plasma Arc, MSW Mass Burn, and Refuse Derived Fuel) – Of the waste to energy options, MSW mass burn is likely the preferred option, even though plasma arc has a slightly higher score in the long term. The primary reason for this is that mass burn is proven technology, while plasma arc is still in early demonstration. The substantially higher cost of a refuse derived fuel plant does not appear to outweigh its slightly higher ancillary benefits. For all the waste to energy options, a tipping fee higher than the

\$50/ton number used for this screening process will significantly enhance its score. A tipping fee of \$65/ton or higher would give mass burn an overall score very near landfill gas and wind.

- **Ocean Thermal** – The relatively moderate projected cost of offshore ocean thermal makes it a potentially attractive resource in the 10 to 20 year timeframe. The projected cost assumes that the technology will develop through continued R&D, demonstration projects, and successful commercial installations. Given that Hawaii is one of the better locations in the world for ocean thermal, KIUC should monitor development of this technology.
- **Solar Thermal** – Similar to ocean thermal, solar thermal power could be an interesting option for KIUC – provided investments are made in the technology to allow continued cost and performance increases sufficient to match the projections presented here. Central station solar thermal is much more attractive economically than solar photovoltaics.
- **Biofuels** – Despite having high ancillary benefits (job creation, excellent fit to KIUC, and good incentives) ethanol and biodiesel appear unattractive due to high cost. The assumed fuel cost (\$15-23/MBtu) may be competitive for transportation markets, but not for power production. That said, there is currently only a very limited market for alternative fuels in Hawaii, so it is difficult to estimate what the final fuel price will be for power production applications. Incentives and subsidies may significantly help biofuels. Further, KIUC could very easily integrate biodiesel into its existing fuel supply system without high capital costs or extensive equipment modifications.
- **Wave** – The prospects for wave energy are highly dependent on successful R&D, demonstration and commercialization of the technology. Kauai could be an ideal place for wave energy demonstration projects if incentives for demonstration project development are available. KIUC should monitor development of the technology for possible application in Kauai.
- **Solar photovoltaic** – Solar photovoltaics are the most expensive renewable energy technology. It is projected that solar photovoltaics will remain too expensive to be applied competitively at utility scale throughout the 20-year evaluation period. However, solar can be economical in niche applications (remote power supply, etc.) or when heavily subsidized. Finally, solar photovoltaics have extremely high public appeal, and despite their high cost, they are often a part of a utility's generating portfolio for this value alone.

- **Multi-fuel Generating Technologies** (Reciprocating Engines, Combustion Turbines, Microturbines, Fuel Cells) – Reciprocating engines and combustion turbines are fully commercial technologies offering competitive cost, reliable performance and good fuel flexibility. Microturbines and fuel cells do not currently offer the same cost / performance ratio, although it is projected that the gap will close over the next twenty years. The decision between engine generators and combustion turbines usually comes down to size. Combustion turbines are often preferred for applications greater than 5 MW, and engine generators for smaller sizes.

Black & Veatch recommends that landfill gas, wind, hydro, direct fired biomass, and MSW mass burn be examined for the rest of this report. The conclusions of the screening analysis are summarized in the table below.

**Table 4-13. Renewable Technology Screening Summary Conclusions.**

**Attractive options, regardless of timeframe**

Landfill gas  
Wind  
Hydro  
Direct fired biomass / biomass cofiring  
Waste to energy (MSW mass burn)  
Reciprocating engines (< 5-10 MW)  
Combustion turbines (> 5-10 MW)

**Possibly attractive in mid to long term pending successful technology development**

Ocean thermal  
Solar thermal  
Wave  
Waste to energy (plasma)

**Less cost effective options**

Waste to energy (refuse derived fuel)  
Biofuels  
Solar photovoltaics  
Microturbines  
Fuel cells

**Very limited or no potential**

Geothermal  
Anaerobic digestion (animal manure, sewage sludge)  
Ocean tidal