12.0 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.[113]

Figure 12-1 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. However, over the range of oil prices examined for this analysis, biomass combustion is always more expensive with a lower bound of about $180/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.

[113] Personal communication from Jeff Deren, KIUC, November 23, 2004.

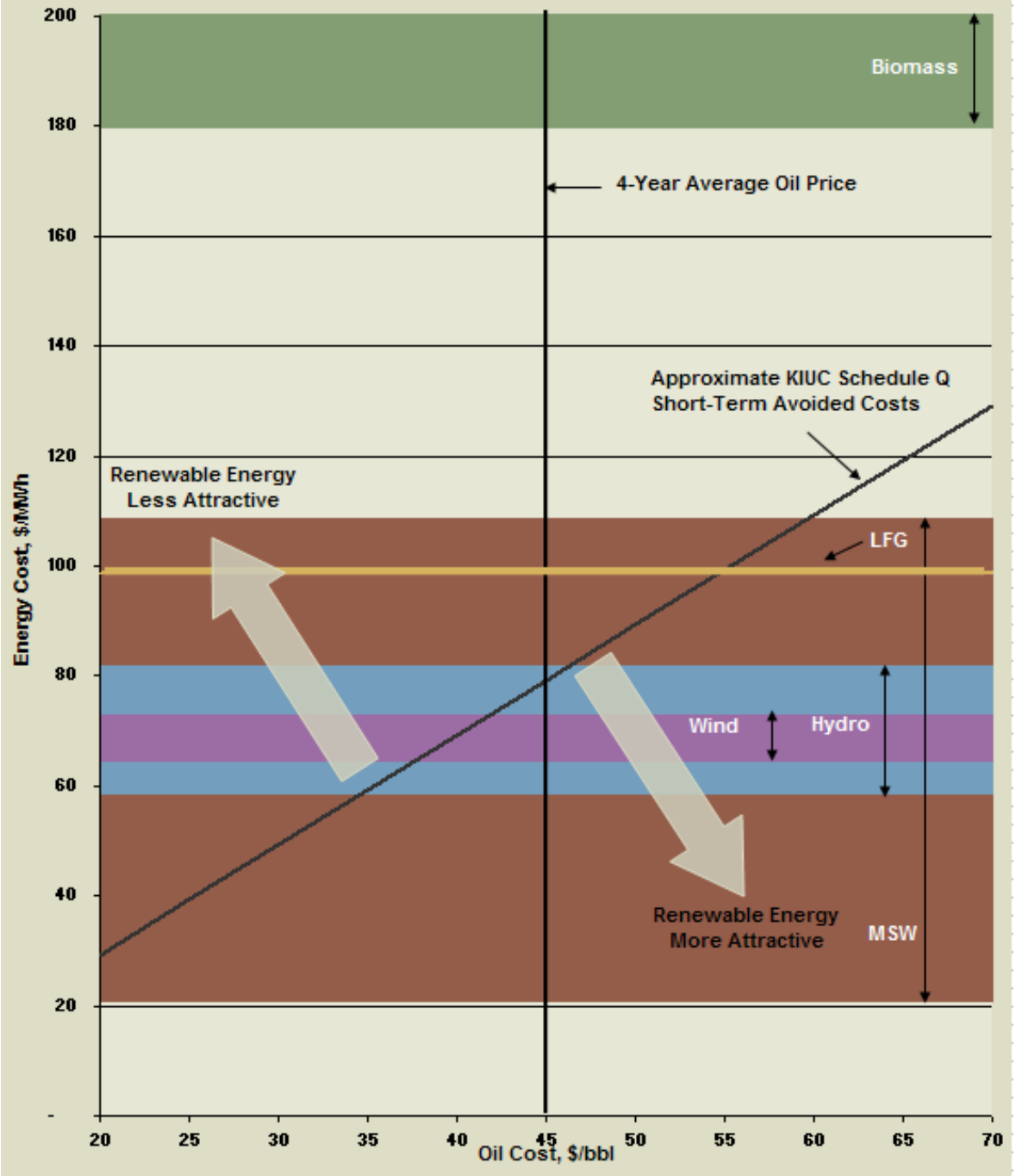

Figure 12-1. Break-Even Cost Analysis for Renewable vs. KIUC's Short Term Avoided Costs.

Appendix A. Hydro Prospects Identified

Region		Quad	River		Power	Conceptor		Corps	Report	Year	Forebay				Gravity Conveyance		Penstock		Powerplant		Afterbay		Head	Basin	USGS	Falls	Flow (cfs)			Size (kW)		Turbine		Plant	E (GWh/yr)		Const.	O&M
Project Name	Type	Sheet	Source	Owner	Purchaser	Name	Year	No.	No.*	Built	Name	Elev.	(feet)	(ac-ft)	Name	(feet)	(feet)	(inch)	Name	Elev.	Name	(ac-ft)	(feet)	(mi^2)	Gage	Name	Avg.	Prop.	Min.	Exst.	Prop.	No.	Type	Factor	Exst.	Prop.	($M)	($k/yr)
North																																					
Wainiha	run-of-river	Haena	Wainiha	Kaua'i Coffee	KIUC			E1	1,6,11	1906		699	20						Wainiha		-	-	564	13	16010800				0	3,800	?	4	Pelton		24	-	-	
Wainiha	run-of-river	Haena	Wainiha	Kaua'i Coffee	KIUC	McBryde	1985	-	11	-		1154	14				7,000	48		722	-	-	433		16108000	Puu Wainui	100	139	3	-	4,000	2	Pelton		-	22.5	$10.0	
Wainiha (1978)	run-of-river	Haena	Wainiha	Kaua'i Coffee		Corps	1978	-	8,14	-				0			6,800			0			189	10	16108000		143	31	3	-	430			90%	-	3.77	$6.0	$22
Wainiha (Hirai)	run-of-river	Haena	Wainiha	Kaua'i Coffee		Hirai	1981	-	8	-							7,000						290		16108000	Puu Wainui	139			-	3,700	2	1.6,2.1	54%	-	17.4	$6.1	
Kauai	storage		Wainiha	State of Hawai'i				-	6	-																				-	25,000				-	133.6	$59.6	
North	run-of-river		Lumahai	Garratt-Callahan				-	5, 6, 9	-																				-	6,000				-	32.1	$16.6	
Lumahei (1978)	run-of-river	Hanalei	Lumahei			Corps	1978	-	8,14	-													312		16106000			26	3	-	590			90%	-	1.5	$7.2	$32
Lumahai (1981)	run-of-river	Hanalei	Lumahai			Hirai	1981	-	8,13								11,400		Lumahai River				312		16106000	-	120			-	2,800	2	1.5, 1.3	57%	-	14.1	$6.2	
Hanalei (storage)	storage	Hanalei	Hanalei			Corps	1978	-	8,14	-				11,800			8,000						261					73	3	-	1,400			90%	-	12.3	$35.0	$58
Hanalei (1978)	run-of-river	Hanalei	Hanalei			Corps	1978	-	8,14														263		16103000			9	3	-	170			90%	-	5.17	$5.6	$23
Hanalei (1981, 1)	run-of-river	Hanalei	Hanalei			Corps	1981	-	8,13	-			10										263	10			104			-	4,500				-	16.5	$12.0	
Hanalei (1981, 2)	run-of-river	Hanalei	Hanalei			Hirai	1981	-	8	-							20,000						360		16101000		87			-	2,550			51%	-	11.5	$8.8	
Hanalei	run-of-river	Hanalei	Hanalei	Hanalei Hydro			80's	-	6, 8, 9	-																				-	6,000				-	2.9	$9.3	
Koloko	storage	Anahola	offstream	Mary N Lucas		Corps	1980	-	5,13	1890	Koloko	488	44	1,800	-	-								1		-	6			-	68				-	0.2		
Wehrheim's				John Wehrheim	n/a	Pacific Hydro		E8	5	1979																				?	-				?	-		
Namahana Farms						Pacific Hydro	2004	-																						-	3,500				-	?		
East																																					
Rancho Hydro	diversion		Anahola	John Harder				P3	5	-																				-	1.5				-	0.005	-	
Hanalei (Tunnel)	diversion		Hanalei			Hirai	1981	-	1,8	-					Hanalei Tunnel	6,028	8,000						510		16100000		27			-	1,400			67%	-	8.2	$3.7	
Upper Wailua	run-of-river		Hanalei	Island Power				-	6,9,11	-																			5	-	1,260				-	6.5	$2.5	
Wailua Reservoir (Above)	run-of-river	Kapaa	N. Fork Wailua	EKWUC		USBR	2004	-	2	-	Wailua			737	-	-	2,350	48			-		82			-		60	15	-	309	1	Francis		-	1.7	$3.0	
Wailua Reservoir (Below)	run-of-river	Kapaa	N. Fork Wailua	EKWUC		USBR	2004	-	2	-	Wailua			737	-	-	16,000	48			-		432			Kaholalele		60		-	1,629	1	Turgo		-	8.8	$11.7	
(Lower) Wailua	run-of-river	Kapaa	N. Fork Wailua	Symbiotics	KIUC	Symbiotics	2001	-	3-6,9,12,13	-	yes		28	430	-	-	4,800	96	Lower Wailua		-	-	262			Wailua	116	150	15	-	6,600	2	Francis		-	16.4	$13.1	$200
Wailua Ditch	run-of-ditch	Kapaa	N. Fork Wailua	EKWUC		USBR	2004	-	2	-	Wailua			737	Wailua Ditch											-				-	?				-	?		
Lateral 6	run-of-ditch	Kapaa	N. Fork Wailua	EKWUC		USBR	2004	-	2	-	Wailua			737	Lateral 6						Twin					-				-	?				-	?		
Upper Kapahi	storage	Kapaa	N. Fork Wailua	EKWUC		USBR	2004	-	2	-	Upper Kapahi			92							Twin					-				-	?				-	?		
Reservoir 21	storage	Kapaa	S. Fork Wailua	EKWUC		USBR	2004	-	10	-	Reservoir 21															-				-	?				-	?		
Aahoka	storage	Kapaa	S. Fork Wailua	EKWUC		USBR	2004	-	2	-	Aahoka															-				-	?				-	?		
Upper Lihue (Waiahi)	run-of-river	Waialeale	S. Fork Wailua	JMB	KIUC	Pacific Hydro	2003	E6	1,2,4,5,8,10,13	1931					Iliiliula Ditch		833	37	Upper Lihue	1050	-	-	247				27	32		500	800	1	Pelton		3.1	4.9	$2.0	
Lower Lihue (Waiahi)	run-of-river	Waialeale	S. Fork Wailua	JMB	KIUC	Pacific Hydro	2003	E7	1,2,5,8,13	1941					Iliiliula Ditch		783	37	Lower Lihue		-	-	205		16068000		48			800	1,100	1	Francis		6.1	8.0	$1.6	
Wailua (Corps)	run-of-river		S. Fork Wailua	Lihue Plantation		Corps	1981	-	13	-			10	310									310	23	16060000	Wailua		150		-	8,400				-	18.7	$12.9	
Wailua (Hirai)	run-of-river		S. Fork Wailua	-	-	Hirai	1981	-	8	-							20,000						360	-	16060000	Wailua				-	11,700	2	3.2, 8.5	25%	-	25.2	$14.0	
Waialeale	storage		S. Fork Wailua	State of Hawai'i		BCA	1978	P2	5,8,13,14	-			185	22,700									559	18			57			-	9,200				-	50.0	$72.0	
Kapaia	storage		Hanamaulu	Lihue Plantation		Corps	1981	-	6,8,13	1910	Kapaia		45	1,114	-	-								2			10			-	120				-	0.18		
South																																					
Mauka Ditch	run-of-ditch	Koloa	Waihohonu	Hawaiian Mahogany		USBR	2004	-	6,11,13	1919	Puu O Hewa	580		123	Mauka Ditch				Malumalu				150			-	6			0	100				-	?		
Upper Alexander	storage	Koloa	Wahiawa	Kaua'i Coffee		USBR	2004	-	2,10	-	Alexander																			-	?				-	?		
Kalaheo	storage	Koloa	Wahiawa	Kaua'i Coffee	KIUC	Corps	1981	E5	1,8,13	1931	Alexander	1533	119	2,540		8,000	5,000		Kalaheo				699	3			7			1,000	1,000	1			2.1	2.1		
Alexander/Elua	pumped	Koloa	Wahiawa	Kaua'i Coffee		Hirai	1980	-	8	-	Alexander	1533	119	2,540		9,700				700	Elua		900							-	8,100				-	-14.4	$17.0	
Southwest																																					
Kaumakani	run-of-river	Waimea	Makaweli	Gay & Robinson	KIUC	Corps	1981	E4	3,8,13	1920			10						Kaumakani				211	5			10			1,250	1,250				3.1	11.4		
(Waimea) Mauka	run-of-river	Waimea	Waimea	ADC	KIUC	Corps	1981	E2	1,6,8-10	1954			10		Kekaha Ditch			42	(Waimea) Mauka	550			265	32	16031000			55		1,000	3,900				5.0	8.9	$3.2	
Waiawa	run-of-ditch	Kekaha	Kahoana	ADC	KIUC			E3	5,8	1907					Kekaha Ditch		1,000		Waiawa		-	-	280			-				500	700				1.9	4.0	n/a	
Kekaha-Waimea	run-of-river	Kekaha	Waimea	AMFAC Sugar		USBR	2004	-	2	-					Kekaha Ditch		1,850	36	Waimea (Makai)	30	-	-	430		16022000			60	22	-	1,700	1	Turgo		-	-	$3.3	
	run-of-ditch			Gay & Robinson		Vorfelt	2004	-	11	-		1000											800				116			-	5,000				-	?		
Koula Ditch	run-of-ditch			Gay & Robinson		Moe		-		-	-	600		0	Koula Ditch					0			600				108			-	?				-	?		
	storage	various	Kawaikoi	Gay & Robinson		Moe		-		-			20		Kokee Ditch												85	155	0	-	?				-	?		
Kokee (1964)	storage	various	Kawaikoi	AMFAC Sugar		DNLR	1964	P1	6, 8, 9	-	Kawaikoi	3400	240	36,215	Kokee Ditch	-			Puu Opae	2000	Puu Opae		1,400					8		-	10,000				-	53.4	$26.2	
Kokee (Corps)	run-of-ditch	Kekaha		AMFAC Sugar		Corps	1978	-	14	-					Kokee Ditch								982	1	16014000	-		6	0	-	430			90%	-			
Kitano (1st phase)	run-of-ditch	Kekaha	Haeleele	AMFAC Sugar		DNLR	1984	P4	5,6,8,9,13	1928	Kokee Ditch		110		-	-	9,100	24	Kitano	2123	Kitano	110	800		16014000		17	29	10	-	1,650	2	.7,.95	51%	-	8.0	$4.8	
Puu Opae (2nd phase)	run-of-ditch	Kekaha		AMFAC Sugar		DNLR	1984	P5	5,8	-	Kokee Ditch				-	-	13,700	24	Puu Opae	2000		31	1,030					12		-	700				-	?		
Mana Ridge (3rd phase)	run-of-ditch	Kekaha	Kawaikoi	AMFAC Sugar		DNLR	1984	P6	5,8	-	Kawaikoi	3400	182	18,412	-	-	16,000	30	Mana Ridge	2212	Mana Ridge	92	1,200					33	2	-	2,000	1	Pelton		-	10.7	$16.1	
Puu Lua-Kitano	run-of-ditch	Makaha	Kawaikoi	AMFAC Sugar		USBR	2004	-	2	-	Puu Lua	3268		798	-		29,716	36	Kitano	2123	Kitano	110	1,145		16014000	-	24	40		-	2,970	1	Pelton	60%	-	15.8	$17.6	$254
Kitano-Waimea	run-of-ditch	Kekaha		AMFAC Sugar		USBR	2004	-	2	-	Kitano	2123		110	-		26,400	30	Waimea Makai	30	-	-	2,093			-		30	10	-	4,078	1	Pelton	48%	-	17.1	$16.1	$233

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Ownership Changes

McBryde Sugar = Alexander and Baldwin = Kaua'i Coffee
Olokele Sugar = C Bruir = Gay & Robinson
Kekaha Sugar (late 90's) = AMFAC = State of Hawaii = ADC
Lihue Plantation (2000) = AMFAC = JMB

Existing - Promising for upgrade
Existing - Not promising for upgrade
New - Promising projects