

## 10.0 Landfill Gas

There is only one viable landfill gas project on Kauai, located at the Kekaha landfill. (There is one smaller landfill, but it is not suitable for development.) Black & Veatch estimated the energy production of this project after landfill closure in 2009. A project based on reciprocating engine technology could produce about 800 kW. The results of this assessment are detailed here.

### 10.1 Basis for Assessment

Black & Veatch reviewed the Landfill Gas (LFG) Utilization Feasibility Study for the Kekaha Landfill by SCS Engineers dated April 2004. This report provided information about the operating landfill at Kekaha with financial analysis results from the EPA LMOP E-PLUS program.

Three scenarios were evaluated by SCS; the primary option utilized an internal combustion (IC) engine for power generation.

### 10.2 Assessment of Contributing Resource

The source of the LFG is the Kekaha Landfill. It opened in 1953 and was originally scheduled to close in 2004. A closure extension until 2009 has recently been granted. SCS modeled landfill gas production assuming a 2004 closure. Black & Veatch extended the model to account for closure in 2009. The landfill is currently producing LFG, but it is not collected. A project could conceivably come on-line before 2009 to take advantage of gas being produced now. Additional capacity could be added later after the landfill is completely capped. However, such generation staging was not assumed for this study.

It seems that few formal records were kept for waste deposits and waste-in-place (WIP) until recently. It is estimated by the landfill operators that the annual deposit rate was 14,600 tons per year until 1993. At that point, records show a dramatic increase up to the current rate of 79,000 tons per year.

SCS used a program called E PLUS that was developed by the EPA LMOP to estimate landfill gas generation potential. The program uses a first order decay model based on the amount of WIP and empirical gas generation constants. Based on the SCS model, the year of the maximum WIP for the Kekaha Landfill will be 2004, the year of closure. Accordingly, the maximum gas generation will occur that year. SCS estimated the maximum gas flow will be 379 cubic feet per minute (cfm). Thereafter, the gas flow will decline, with the estimate for 2018 being 243 cfm.

Black & Veatch has modified the analysis to determine the LFG generation potential assuming a closure date of 2009. The analysis was based on the first order decay equation:

$$Q_M = \sum_{i=1}^n 2 k L_o M_i (E^{-kt_i})$$

where:

- i = year, through the last projection year (n)
- $Q_M$  = maximum expected LFG production flow rate (m<sup>3</sup>/yr)
- K = methane generation rate constant (1/yr)
- $L_o$  = methane generation potential (m<sup>3</sup>/Mg)
- $M_i$  = mass of solid waste disposed of in the i<sup>th</sup> year (Mg)
- $t_i$  = age of the waste disposed in the i<sup>th</sup> year (years)

Black & Veatch's gas estimates are shown in Figure 10-1. In this case, the maximum gas flow is approximately 465 cfm and occurs in 2009.

Very little data has been provided regarding the quality of the gas. It is stated that the measured methane content is 40 percent. This is considered low for LFG and is borderline for use in IC engines. Methane typically constitutes 45 to 50 percent of the landfill gas. Other important qualities that have not been discussed are the oxygen, moisture, siloxane, halide, chloride and sulfur (H<sub>2</sub>S) contents. High oxygen content (more than 2 percent) can be an indicator of imbalanced gas collection flows. With adjustments, the oxygen level can be reduced and methane production increased.

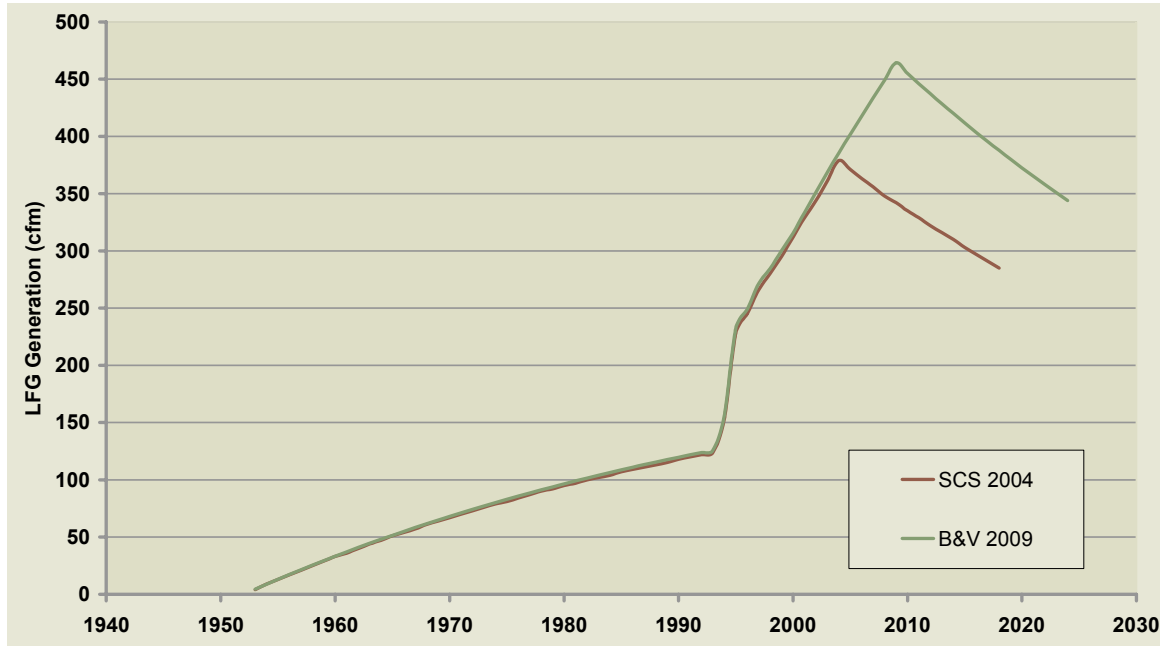


Figure 10-1. LFG Generation Estimates by Year.

### 10.3 Project Option Screening

Various uses can be envisioned for the LFG from Kekaha Landfill. The most conventional is combustion in an IC engine at the landfill for generation of electricity. Others include direct use of the gas for heating or displacement of fossil fuel consumption in a nearby, existing engine generator. These could be options in Kauai, but Black & Veatch is unaware of firm offtakers proposed for either. Only the IC engine option has been considered in this review.

### 10.4 Project Technical Description

Compared to many of the other renewable energy options, development of landfill gas projects is relatively straightforward. One of the more significant aspects will be development of gas collection facilities, which Kekaha does not currently have. The collection system consists of vertical gas wells, wellheads, blowers and gas cleanup equipment. Flares are also required for destruction of LFG during periods of engine outages. The Landfill is not currently required by law to have or install these collection facilities. The balance of the project consists of installing an engine generator and interconnecting the project to the electrical grid.

## 10.5 Power and Energy Production

### 10.5.1 Plant Performance

The plant efficiencies for IC engines are typically in the range of 20 to 30 percent. Engine generators burning LFG that are considered “new and clean” typically have an efficiency of about 30 percent. This equates to a net plant heat rate of about 11,500 Btu/kWh. Historical data for LFG projects show that the heat rate may increase up to 14,500 Btu/kWh, depending on the effectiveness of the O&M plan. In addition, due to part load inefficiencies, the net plant heat rate will degrade over the life of the project as the amount of gas declines.

Based on the gas production estimates, the plant capacity will be approximately 810 kW at the time of commissioning in 2009. The capacity will remain constant at 810 kW over the first five years as the total amount of gas generated exceeds the fuel burn rate of the engine. Over time, the capacity will dwindle as the gas supply decreases. Because of the decreasing generation, it is assumed that the project life will be limited to 15 years. Based on the model predictions for gas flow in 2024, the project capacity will decrease to around 703 kW.

### 10.5.2 Operating Profile

With a capacity factor as high as 85 percent, LFG plants are baseloaded. Landfills typically provide very steady gas flows. There is very rarely opportunity for gas storage. All gas that is generated while the plant is in an outage will be flared. This plant will operate similarly and provide baseload power.

## 10.6 Cost of Energy

### 10.6.1 Capital Cost

Black & Veatch has estimated the total capital cost of the LFG project, shown in Table 10-1. The engine generator set line item cost was provided by a Caterpillar distributor. The costs for the installation of the engine set and the electrical system were based on Black & Veatch historical data. LFG collection system costs can be quite varied. This estimate is based on an expected number of gas wells and corresponding horizontal collection lines for a landfill of this size.

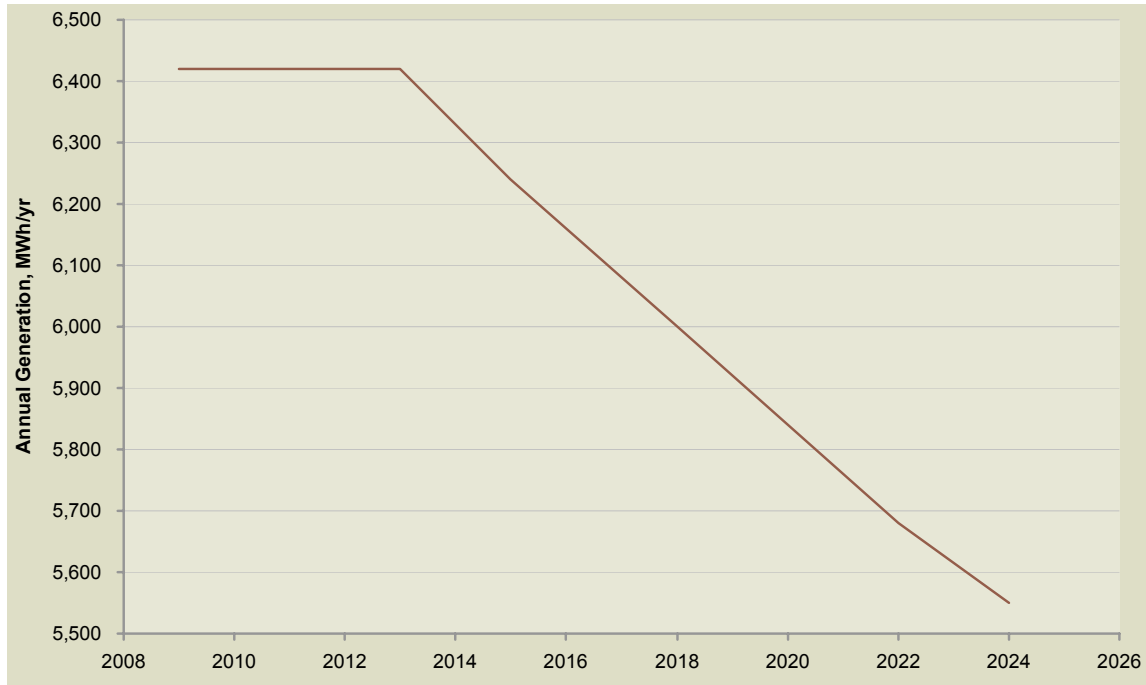


Figure 10-2. Annual Electrical Generation.

<b>Table 10-1. LFG Capital Cost Estimate.</b>	
<b>Construction Item</b>	<b>Cost</b>
Engine Generator Set	599,000
Electrical System	301,000
LFG Collection System	1,580,000
<i>Total Direct Cost</i>	<i>2,480,000</i>
<i>Indirect Cost</i>	<i>748,000</i>
<b>Total Capital Cost</b>	<b>3,228,000</b>
<b>Total Capital Cost, \$/kW (810 kW)</b>	<b>3,965</b>

### 10.6.2 Operating and Maintenance Costs

Black & Veatch has estimated that the first year O&M cost will be \$190,000. This is inclusive of fixed and variable costs. It is assumed that one full time staff will operate and maintain the facility, likely remotely. Other items included are planned replacements of bearing and heads and routine maintenance such as changing the oil. Periodic engine rebuilds are also included as planned maintenance costs.

### 10.6.3 Applicable Incentives

There are several federal incentives available for the development of landfill gas power generation facilities. The federal production tax credit provides a \$9/MWh incentive for five years following the initial commercial operation date of the facility, however the facility must be owned by a taxable entity to claim this credit. The PTC is included in the life-cycle cost analysis for the developer ownership scenario. Various federal grants and low interest loan programs would be applicable to these projects; however, the exact impact of these programs is uncertain and not quantified at this time. Therefore, no incentives are included for the KIUC ownership scenario in the life-cycle cost analysis.

### 10.6.4 Life-cycle Economics

The life-cycle cost of providing power from the potential landfill gas-to-energy project at the Kekaha landfill was calculated with the levelized cost. The project performance and economic assumptions as well as the results of the life-cycle cost analysis are presented in Table 10-2. Figure 10-3 shows an example life-cycle cost calculation for the Kekaha Landfill Gas project.

<b>Table 10-2. Landfill Gas Life-Cycle Economic Assumptions (\$2005).</b>		
	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)
Developer Levelized Cost	2009\$/MWh	119.96
Developer Premium	2009\$/MWh	(40.40)

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.

<b>Kekaha Landfill</b>											
<b>Landfill Gas</b>											
<b>Plant Input Data</b>			<b>Economic Input Data</b>				<b>Rate</b>		<b>Escalation</b>		
Capital Cost (\$1,000)		3,633	First Year Fixed O&M (\$1,000)				101.69		3.0%		
Total Net Capacity (MW)		0.81	First Year Variable O&M (\$1,000)				110.43		3.0%		
Capacity Factor		86%	Fuel Rate (\$/MWh)				0.00		3.0%		
Full Load Heat Rate, Btu/kWh (HHV)		11,491.00									
Debt Term		15									
Project Life		15									
Hours per Year		8,760	Present Worth Discount Rate						5.0%		
			Levelized Fixed Charge Rate						9.63%		
Year	Annual Capital Cost (\$1,000)	Fixed O&M (\$1,000)	Variable O&M (\$1,000)	Fuel Rate (\$/MBtu)	Fuel Cost (\$1,000)	Total Cost (\$1,000)	PW Total Cost (\$1,000)	Busbar Cost (\$/MWh)	PW Cost (\$/MWh)	Avoided Capacity Cost (\$/kW)	Avoided Energy Cost (\$/MWh)
2009	350	102	110	-	-	562	535	91.66	87.30	0.00	111.89
2010	350	105	114	-	-	568	516	92.70	84.08	0.00	121.46
2011	350	108	117	-	-	575	497	93.77	81.00	0.00	131.10
2012	350	111	121	-	-	582	479	94.87	78.05	0.00	133.40
2013	350	114	124	-	-	589	461	96.00	75.22	0.00	139.93
2014	350	118	128	-	-	596	445	97.17	72.51	160.34	146.48
2015	350	121	132	-	-	603	429	98.37	69.91	162.00	155.09
2016	350	125	136	-	-	611	413	99.61	67.42	160.15	159.54
2017	350	129	140	-	-	619	399	100.89	65.03	192.08	155.25
2018	350	133	144	-	-	627	385	102.20	62.74	192.80	164.57
2019	350	137	148	-	-	635	371	103.56	60.55	192.35	168.47
2020	350	141	153	-	-	644	358	104.95	58.44	183.14	166.80
2021	350	145	157	-	-	652	346	106.39	56.42	203.74	163.22
2022	350	149	162	-	-	661	334	107.87	54.48	200.11	168.86
2023	350	154	167	-	-	671	323	109.39	52.62	196.32	159.73
<b>Levelized Bus-bar Cost, \$/MWh</b>								<b>98.83</b>			
<b>Net Levelized Cost (\$1,000)</b>								<b>606.04</b>			
<b>Levelized Avoided Capacity Cost, \$/MWh</b>								<b>14.11</b>			
<b>Levelized Avoided Energy Cost, \$/MWh</b>								<b>146.25</b>			
<b>Levelized Cost Premium, \$/MWh</b>								<b>(61.54)</b>			

Figure 10-3. Kekaha Landfill Gas 15-Year Busbar Cost Calculation.

## 10.7 Advantages and Disadvantages of Technology

### 10.7.1 Fit to KIUC Needs

This landfill gas project is a good, but not ideal fit to KIUC's needs. It is a small amount of generation that is well-sized to be of value to KIUC. Further, the capacity of the system fits well with KIUC's current system needs.

### 10.7.2 Environmental Impact

The environmental benefit of this project would be twofold. The first benefit is preventing additional methane from escaping to the atmosphere. Methane is a potent greenhouse gas – 21 times more damaging than carbon dioxide. Capturing it and burning it in an engine or a flare reduces greenhouse gas emissions. Second, because the methane is not actively collected, there is potential that it could build up and cause an explosion in the future. Installing an LFG project would greatly reduce this possibility.

### **10.7.3 Socioeconomic Impact**

This LFG project would have relatively minimal socioeconomic impact. It is not expected that more than one long term salaried position would be created by the project. Construction labor impacts will also be relatively low compared to the other renewable energy projects.

### **10.7.4 Incentives and Barriers**

LFG projects have good appeal in terms of incentives and barriers. Generally, the public understands and accepts the technology as mature and environmentally positive. The project would be quick to implement with minimal planning, engineering and permitting compared to other technologies. KIUC already maintains staff who are knowledgeable of IC engine operations. There would be minor nuances to learn about burning LFG, but the transition would be straightforward. This project has previously been considered and studied, so there is already positive momentum toward implementing the project. Finally, the landfill owner seems willing to consider the project; this can be a significant hurdle for other projects.

There are no significant non-economic barriers perceived for this project.

## **10.8 Next Steps**

The first step that should be taken to advance this project is to definitively understand what the closure date will be. As illustrated earlier, this will have a tremendous impact on the project gas production numbers.

Another early activity to pursue is obtaining and testing a gas sample from the existing landfill. Of primary importance are the lower heating value and gas contaminants. Unsatisfactory results could require additional capital expenditures for gas improvement equipment or modification of landfill operations.

After the gas sampling, the next two steps would be executing a Letter of Intent with the County to establish terms of the development. Execution of this document is a precursor to signing a gas transfer agreement with the County by which KIUC will be entitled to use the LFG. This is analogous to a PPA for landfill gas.