

RENEWABLE ENERGY FEASIBILITY REPORT

KAHULUI, HAWAII



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Executive Summary

This is a feasibility report for a residential renewable energy system at 545 Aloha Blvd., Kahului, Hawaii. There is a strong wind and solar energy resource at this location; we recommend a system that can take advantage of both. Daily household AC loads were determined to be approximately 4.5kW. These values were determined conservatively so our system was designed to support additional load. A 1.7kW solar PV array and a 3kW wind turbine were selected to meet load requirements. Power from each generating system will be regulated and fed into a central battery bank, providing up to 2 days of autonomy. In the case of electricity shortage, a back-up gasoline powered generator was included to provide charging capacity for the battery bank and simultaneous load handling for the household. Total costs were kept under our budget of \$50,000. Federal and state incentives for renewables were outlined and accounted for. The outlook for a renewable system at this location is very good, and we recommend moving forward.

Introduction

This report outlines the feasibility and implementation methods for a renewable energy system at 545 Aloha Blvd., Kahului, Hawaii. Our task was to design an off-grid system that could handle a 4.7kW daily AC load and remain within or under our contract budget. Details of the study include sections on site analysis, method for design and implementation, incentives, total cost, payback, opportunities for improvements, recommendations and an appendix. The goal of this report is to provide our client with the information necessary to proceed with a renewable electricity generation system.

Site Analysis

Kahului is located on the north shore of the Hawaiian Island of Maui. Its latitude is 20.88 degrees north by 156.47 degrees west. It is one of the windiest places in the United States with an average yearly wind speed of 12.8 miles per hour, or 5.7 meters per second. It is also very sunny and warm with an annual average of 5.8 peak sun hours per day. Kahului is an ideal location for a PV system, a wind system, or both.

The average yearly temperature is 24.2°C, with the lowest temperatures occurring between January and April at an average of 22.5°C. The hottest months are June, August, September and October at an average of 25.9°C. This makes ideal conditions (almost STC) all year round for the

operation of batteries and PV panels. The lowest insolation is in December at 5.0 peak sun hours at latitude going up to 6.0 in June.

Hawaii has ideal summer conditions for running a P.V. system because of its high insolation value and low amounts of precipitation, 20 mm per day in June up to 35 mm per day in August. These months have a low average of 5 cloudy days per month. As for wind, the monthly average values stay strong and constant, with the least in January at 4.7 m/s and the most in July at 6.8 m/s (elevation 10m). Kahului is a great site for both of these renewable resources, and the possibility to harness them is fantastic.

Background

The robust wind and solar resource in Kahului allowed for a hybrid wind/solar generating system and so we designed a system which would take advantage of both. Power output for solar is obviously highest in the daytime and non-existent at night, leaving many hours in a day without generating capacity. Coastal winds are often stronger at night due to the uneven temperature between land and water, thus allowing generating capacity to ramp-up for wind just as the solar resource sets for the evening. Additionally, federal and state incentives for both resources allowed for significant and combined cost reductions.

Method

Step One: Estimating Electrical Loads

Determining the parameters of the system first required an accurate approximation of daily electrical loads. A list of appliances and electric devices deemed critical to household functioning was compiled complete with quantities of each device, rated power consumption and output voltages. Time of use factors were taken into account—use hrs/day, use days/wk—to get an accurate average daily load in AC watt hours. Please refer to Appendix Table 1: *Load Estimation* for derived values.

Step Two: Sizing and Specifying Batteries

Once the electrical loads were determined it was possible to size and specify an appropriate battery bank. Appendix Table 2: *Battery Sizing* was used to calculate average amp-hour per day consumption and the number of series-parallel combinations of batteries required to meet this load. Additional variables required to complete the rest of this calculation were:

- DC System Voltage – 48V
 - Due to wire sizing considerations for the wind turbine a 48-volt system size was selected.
- Days of Autonomy – 2 days
 - Calculated using Appendix Table 3: *Days of Autonomy*
 - In short, annual comparisons of cloudy and/or windless days were used to estimate time without a natural energy source. Back-up charging capacity from gas-powered generator was taken into account.
- Battery Discharge Limit – 50%
 - The number of amp-hours drawn from the battery bank would not exceed 50% of the total charge. Represented as 0.5.
- Battery Amp-hour (AH) Capacity – 102 Amp-hours. Specification sheet for batteries provided via the reference page.

Step 3: Sizing and Specifying PV Array and Wind Turbine

After sizing the battery bank it was then possible to determine the size and type of renewable feedstock. Both the solar array and the wind turbine were individually sized to handle the household load of 4.7 kW at their rated output under standard test conditions (STC). Understanding that rated outputs are the best possible estimate of capacity under ideal conditions, we combined the two systems to account for variability in weather conditions. Furthermore, any production approaching standard test conditions for both systems simultaneously will allow the option for increasing household loads.

As a result, a 1.68kW PV array was chosen to fulfill the solar requirements and a 3kW vertical turbine for wind. Many brands and models of both solar panels and turbines are available to fulfill this need. We chose the Suntech™ panels because they suited our design and resource requirements at an acceptable cost. Details for array sizing can be found in Appendix Table 4: *Array Sizing*.

The Ropatec™ wind turbine was selected because of its unique design and acceptable cost. It is noiseless and capable of resisting high winds while also offering a low cut-in speed. Furthermore, it is specifically designed for 48V hybrid applications and is rated for the height required at our location. Calculations of wind speeds can be found on Appendix Table 8: *Bin Method*.

Step 4: Specifying Charge Controllers

The solar array and wind turbine required separate charge controllers. The controller acts as a safety measure that prevents overcharging of the battery bank. They will also ensure that the

battery bank is charged with the correct voltage according to its charge level. Controllers were selected according to the maximum expected amperage coming from the array and turbine. Details for the charge controllers can be found in Appendix Table 5: *Charge Controllers*.

Step 5: Sizing and Specifying an Inverter

The inverter was selected using the total connected household load AC watts. In this case, total connected load was 5525W. Two 4000W Inverter/Chargers were selected to handle this load. The inverters are equipped both with 200% surge capacity, bringing the total surge capacity to 16,000W—or approximately 3 times the connected watts and satisfying inverter safety requirements. The ability for the inverter to have a dual role as a charger was important. It allows for the generator to act as both a charging mechanism for the battery bank while simultaneously handling the household loads. See Appendix Table 6: *Inverter Sizing*.

Step 6: Sizing System Wiring

System wiring was sized according to efficiency parameters (2% voltage drop) and safety requirements. DC and AC disconnect boxes were included in our calculations. In addition, we included wire for grounding system components and equipment and was done according to *National Electrical Code® (NEC)* requirements.

Costs

Price List							
	Number of Units	Unit/\$	Total \$	Wires		per foot/\$	Total
				feet	size		
PV panels	6	\$369.00	\$2,214.00				
Pv Racking	1	\$1,495.00	\$1,495.00	30	#6	\$1.80	\$54.00
Charge Cont.Sol	1	\$159.00	\$159.00	83	#3/0	\$5.46	\$453.18
Wind Turbine	1	\$12,000.00	\$12,000.00	7	#1/0	\$4.00	\$28.00
Wind T. Pole	1	\$4,000.00	\$4,000.00	7	#1/0	\$4.00	\$28.00
Charge Cont.Wi	1	\$539.00	\$539.00	7	#1/0	\$4.00	\$28.00
Inverter	2	\$2,199.00	\$4,398.00				\$591.18
Battery Pack	16.0	\$289.24	\$4,627.84				
Wires			\$591.18				
Total Labour	1	\$2,636.56	\$2,636.56				
Backup Gener	1	\$2,455.00	\$2,455.00				
Miscellaneous			\$2,000.00				
		Total	\$37,115.58				
		Tax	\$3,711.56				
		Grand Total	\$40,827.14				
		Wind Incentive	\$1,500.00				
		Solar Incentive	\$5,000.00				
		Final Total	\$34,327.14				

Payback

We calculated two payback scenarios. The first is a conservative payback approach by which we calculated the yearly household load in kilowatt-hours and multiplied by the cost of electricity in Maui County. The results can be found in the table below.

Revenue/ Savings -Load Based-					
Average Daily load:	4.31	kWh	Cost of electricity	29.45	c/kWh
Annual Saving	463.66	\$	Simple Payback	80.05	Years

The second scenario is an aggressive payback approach by which we calculated our system production potential. In this case, the system is at its maximum power potential and savings, therefore, reflect this output.

Revenue/ Savings -Production Based-					
Average Solar Production:	2.89	MW/yr	Cost of electricity	29.45	c/kWh
Average Wind Production:	1.81	MW/yr	Simple Payback	26.85	Years
Annual Solar Saving	849.93	\$			
Annual Wind Saving	532.46	\$			
Total Saving	1382.38	\$			

Improvements

Due to the ample wind and solar resource available at our site, and our oversized system capacity, there are many opportunities for expanding household electrical loads. During the summer months an excess of power (over 4400 watts) can be expected. This can be used for many applications, such as:

- Increased load capacity
- Powering an electric car
- Powering a solar thermal water heater
- Selling electricity back to the utility
- Sharing power with neighbors
- Charging additional batteries

Incentives

The U.S. federal government is encouraging the development of renewable energy systems by providing a generous tax credit.

- Taxpayers are granted a personal tax credit of up to 30% of total system cost including installation with no upper limit.
- Excess of the credit may be carried over until 2016.

Hawaii is now focusing on development of clean energy by providing incentives to the different types of renewable energy systems.

For solar photovoltaic system, the maximum allowable credits are as follows:

- Single family residential property is eligible for a credit of 35% of actual cost or \$5000, whichever is less.

For wind powered energy systems the maximum allowable credits are as follows:

- Single family residential property is eligible for a credit of 20% of the actual cost or \$1,500, whichever is less.

Conclusions & Recommendations

The available solar and wind resource found at 545 Aloha Blvd., Kahului, Hawaii make an attractive case for installing a renewable energy system. For an off-grid system capable of handling your daily needs with potential for adding additional load we strongly recommend:

- A Hybrid system
 - 1.68kW Solar PV array
 - 3kW Wind Turbine
 - 10kW back-up generator

Please see Appendix Illustrations 1: *SketchUp Illustrations* for 3D illustrations of your system for your location.

References

Backup Generator	http://www.grainger.com/Grainger/BRIGGS-STRATTON-Portable-Generator
Batteries	http://www.altestore.com/store/Deep-Cycle-Batteries/Batteries-Sealed-Gel-Cell/Trojan-31-GEL-12V-102AH-20HR-Gel-Battery/p9407
Hawaiian Electricity Prices	http://www.heco.com
Inverter	http://solarpenny.com/Apollo-Solar-TSW4048-4000W-48V-120-240-Split-Inverter-304021.htm?categoryId=-1
Panels	http://www.altestore.com/store/Solar-Panels/Suntech-STP280-24Vd-280W-24V-Solar-Panel/p9009/
Racking	www.wholesalesolar.com/pdf.folder/mount%20pdf%20folder/DPWPricingGuide.pdf
Solar Charge Controller	http://www.solarpanelstore.com/pdf/flexmaxspecsheets60-80.pdf
Wind Charge Controller	http://www.altestore.com/mmsolar/Others/C-Series_Datasheet.pdf
Wiring	https://www.colemanair.us/vp_asp/Scripts/Articles/TheBasicsAndBeyond5_WireSize.htm
Wind Turbine Price 1	http://www.mywindpowersystem.com/marketplace/ads/3-x-used-ropatek-6kw-residential-wind-turbines-for-sale-great-condition/
Wind Turbine Price 2	http://www.brinaco.cz/innovativbau/pdf/Prices_Windrotor_2005.pdf
Wind Turbine Spec 1	http://greennclean.ca/wp-content/uploads/2009/04/3kw-sheet.pdf
Wind Turbine Spec 2	http://www.ropatec.com/download/EN_datasheet.pdf