Evaluation of West Hawaii Civic Center's Transportation & Energy Use

M. Kuss, T. Markel, M. Simpson, M. Helwig, M. Jun, and K. Kelly

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP
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Contract No. DE-AC36-08GO28308

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Prepared under Task No(s). IDWH0200 and IDWH0250

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West Hawaii Civic Center Sustainable Transportation Analysis

Abstract

The West Hawaii Civic Center Sustainable Transportation Analysis is an effort funded as part of the greater Hawaii Clean Energy Initiative. This paper will report on the state of WHCC's 250 kW PV array, and demonstrate how WHCC can utilize their solar PV to its maximum capabilities using plug-in vehicles. A GPS survey was conducted of WHCC fleet vehicles to determine their usage behavior, and specific recommendations for vehicle replacements were made, based on currently available PEVs.

Introduction to the West Hawaii Civic Center

The West Hawaii Civic Center is a hub of local county government for the Big Island. Located in Kailua-Kona, the West Hawaii Civic Center is the consolidation of 22 county agencies which were previously scattered across the island, as well as one state agency. The facility hosts 220 employees who provide services such as building inspection and licensing, vehicle registration, and the mayor's office. The facility was designed to accommodate additional employees as the population grows over time. Additionally, a community center and pavilion are available to groups for meetings. The West Hawaii Civic Center was designed and built to be a resource to the local residents.

Facilities

The structure is an 85,000 square foot complex which replaced an annual $1.01M in leasing costs. There is enough parking to accommodate 250 vehicles; the top floor of the parking structure is shaded by the 250 kW solar PV array shown in Figure 1. In addition, the building is certified LEED Gold by the US Green Building Council, meaning that the building design and construction took significant steps to reduce environmental impact and energy consumption, while improving the building's indoor environmental and construction quality.

Figure 1. Aerial view of the West Hawaii Civic Center, with the parking structure and 250kW solar PV array in the foreground.

Transportation at West Hawaii Civic Center

Hawaii is the most petroleum-dependent state in the US. Hawaii is unique because petroleum is the primary energy source for the electricity sector, in addition to the transportation sector. In 2009, Hawaii's total consumption was 544 million gallons, of which 97% were imported from non-US sources[1][2]. The cost of petroleum plays a large role in Hawaii's economy, partly due to a significant tourism industry – in a scenario where oil prices rose to $127/bbl by 2020, the real gross state product of Hawaii was predicted to be $1.4 Billion less than in the case where oil prices remained at the 2006 level of $67/bbl[1]. Therefore, by replacing gasoline-fueled vehicles with electric vehicles, and sourcing more power from renewable energy sources which consume no imported fuel, energy costs would be fixed, stabilizing Hawaii's energy price future. Additionally, the remote location of Hawaii makes energy sustainability a security concern, since oil sources are not readily found nearby.

To address these issues simultaneously, aggressive petroleum reduction goals have been set forth by the state of Hawaii. The state and US DOE have set aggressive goals of 70% petroleum reduction by 2030, with interim goals along the way. Figure 2 shows Hawaii's petroleum reductions goals plotted over time.

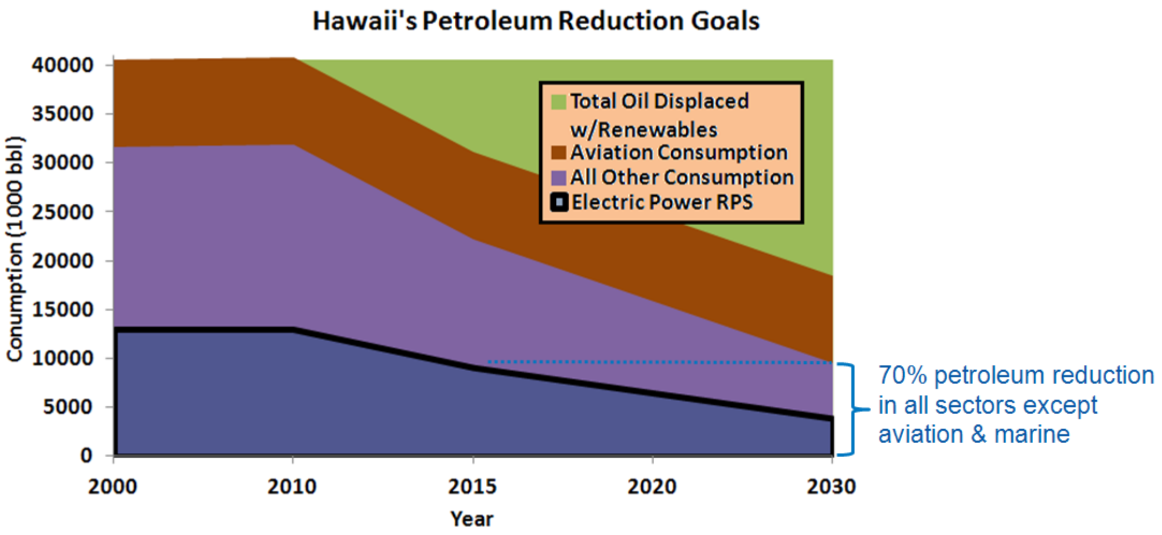

Figure 2. Timeline of Hawaii's petroleum reduction goals set forth by the state &US DOE

The Big Island's grid is powered by more renewables than any other island, giving electrified vehicles the greatest opportunity to reduce petroleum consumption. A breakdown of the HELCO power mix is shown in Figure 3[3]. In addition, the marginal fuel cost of operating a renewable plant is zero, stabilizing future energy prices, and therefore transportation costs.

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[1] M. Coffman, T. Surles, and D. Konan, "Analysis of the Impact of Petroleum Prices on the State of Hawaii's Economy," State of Hawaii DBEDT and University of Hawaii, August 2007.

[2] US Energy Information Administration, "State Energy Data System," June 2011. http://www.eia.gov/state/seds/seds-technical-notes-complete.cfm#consumption

[3] HECO, "About our Fuel Mix," 2011. http://www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=047a5e658e0fc010VgnVCM1000008119fea9RCRD&vgnextchannel=deeaf2b154da9010VgnVCM10000053011bacRCRD&vgnextfmt=defau&vgnextrefresh=1&level=0&ct=article

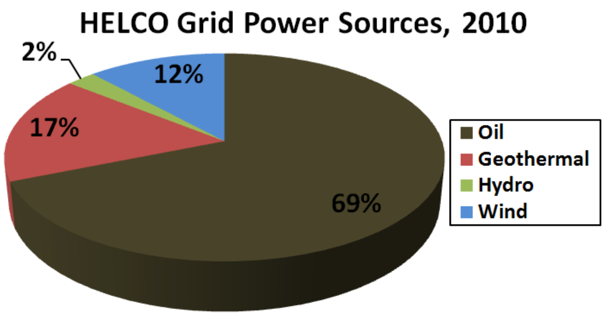


Figure 3. HELCO's power grid energy mix by fuel type, 2010. 31% of the Big Island's power was produced from non-petroleum-fueled plants in 2010, more than any other island

State Vehicles on the Big Island & Fuel Usage

The Hawaii county fleet (including state vehicles) consists of 713 vehicles serving varied functions, shown in Table 1. In order to meet the stated petroleum reduction goals, an interim reduction goal of 22% from 2010 levels must be met by 2015; this implies that the total average fleet efficiency must increase by 22%, or 173,000 gallons of fuel must be offset through electrification. The following fleet analysis will show where West Hawaii Civic Center's fleet fits into the overall vehicle mix, and how to most economically meet these significant petroleum reduction goals.

Table 1. Breakdown of government vehicles and their respective fuel usage on the Big Island

Department	# Vehicles
Public works	259
P&R	175
EM	133
Mass transit	74
Civ defense	22
Other	50
TOTAL	713

Fuel Type	Fuel used (gal)**	GHG emissions CO_2e tons
Diesel (assume B20)	451k	1,878
Gas	337k	1,493
TOTAL	788k	3,371

**Omits fuel used by 88 vehicles that did not have any fuel use data available

West Hawaii Civic Center's Vehicle Fleet & Fuel Usage

West Hawaii Civic Center's fleet consists of 42 vehicles, broken down into the classes shown in Table 2. The vehicles are used for a variety of functions, particularly building, fire, and liquor inspections, as well as transporting senior citizens and county government officials. Fleet vehicles are not currently managed by a single point of contact; because vehicle usage data is dispersed, the per-class average fuel consumption was used to generate an estimate of WHCC's annual fuel usage.

Table 2. WHCC estimated fleet consumption, based on county-wide fleet averages

Vehicle Type	# in WHCC Fleet	Average Annual Fuel Usage (gal)
Light Truck, Van, SUV	36	34k
Passenger Bus	2	6k
Passenger Car	4	3k
TOTAL	42	42k

GPS Travel Survey

NREL's vehicle-grid integration team instrumented 8 vehicles with GPS and CAN data loggers to obtain a more in-depth understanding of vehicle usage patterns at WHCC. By understanding the time-of-day, location, speed, and distance characteristics of the vehicle trips, the charging infrastructure requirements and EV selections can more accurately be determined. Three types of data loggers were used in this study: (1) ISAAC DRU908 GPS/CAN units, (2) Transystems 747ProS GPS units, and (3) Qstarz Travel Recorder XT units. 1-Hz GPS speed and location data was collected during the period July 27–August 26. In all, 32 vehicle driving-days were collected as part of this effort, summarized in Figure 4.

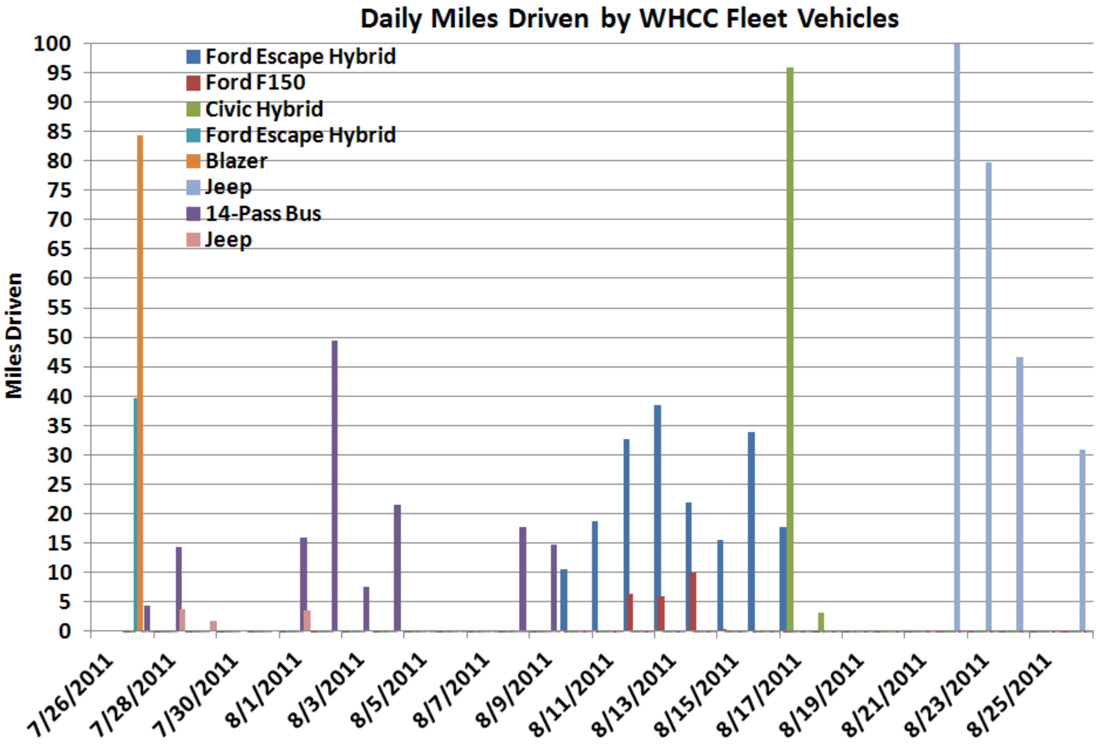


Figure 4. Summary of GPS drive cycle data for WHCC, July-August 2011

No obvious usage patterns emerged on a weekly timescale. Other than the 14-passenger bus operated by the senior center, WHCC vehicles drove highly irregular routes. This is consistent with the purpose of the vehicles; building, fire, and liquor inspections are conducted at different locations each day, and do not repeat routes on the timescale of this study.

Table 3 shows a condensed summary of the GPS data collection results. A majority of WHCC vehicles fall under the light-duty truck or SUV class, which we abbreviate simply as SUVs. The SUV class represents the greatest opportunity for fuel savings because they average the lowest MPG for general purpose vehicles, and are often used to transport people rather than large equipment that would requisite an SUV. Only 1 sedan in the WHCC fleet was instrumented, and was not included in the summary table.

Table 3. Mileage summary from the GPS travel survey

Mileage Summary						
	Vehicles Instrumented	Workdays Collected	Workdays Driven	Avg Daily mileage	Median Daily Mileage	Max Daily Mileage
14-Pass Bus Diesel	1	8	100%	17.9	15.2	50
SUV Gas	6	20	90%	40.1	16.5	197

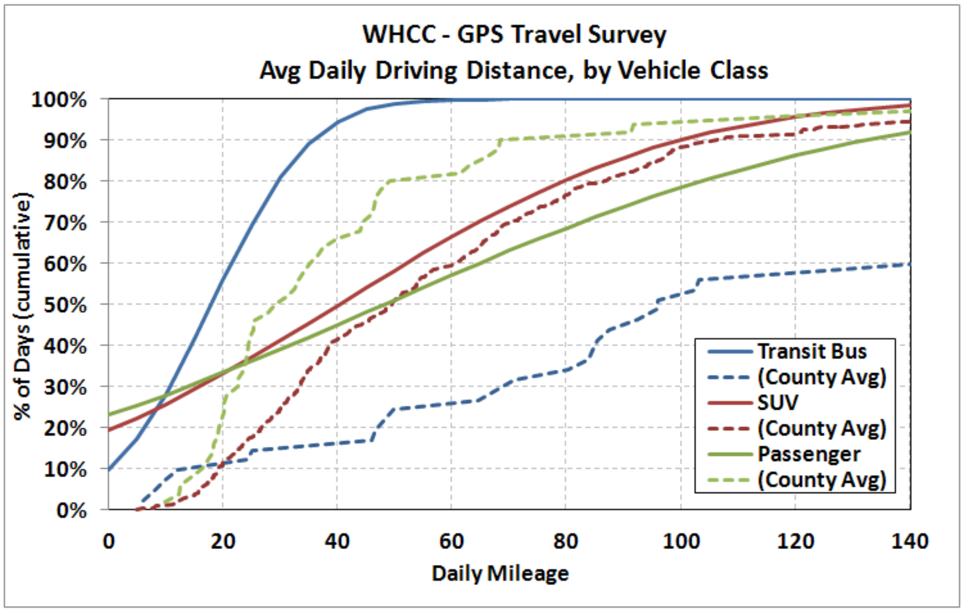
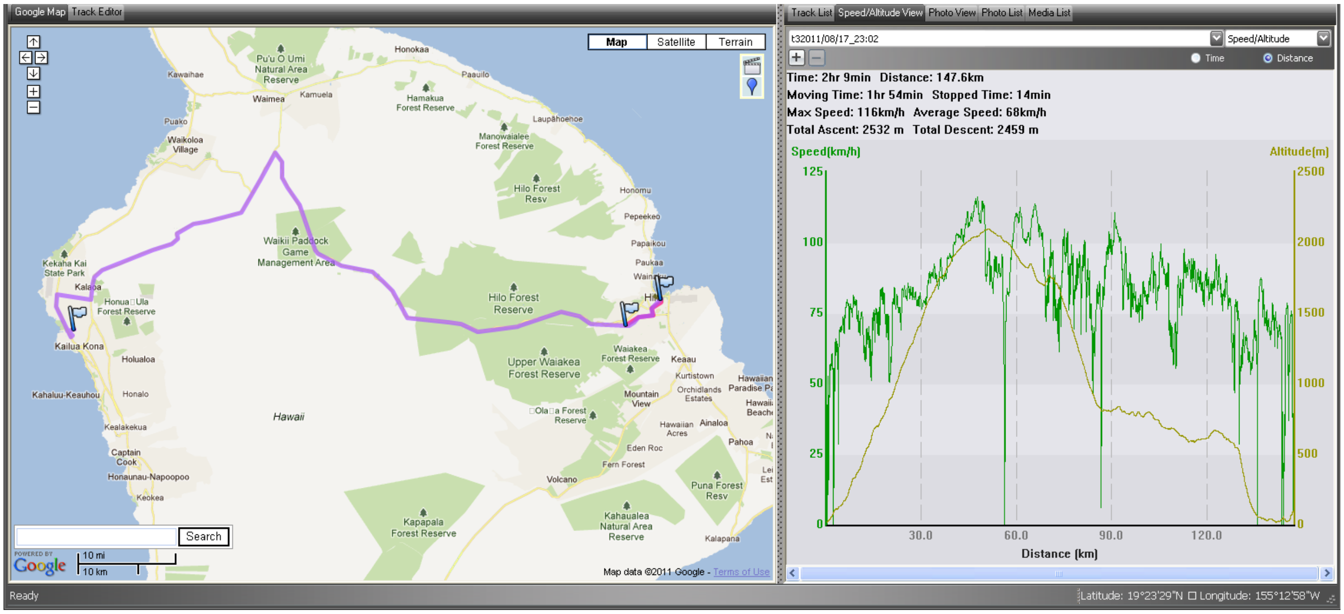


Figure 5. Distribution of daily mileage traveled - WHCC and Hawaii County

In general, WHCC vehicles are driven every weekday. Although the daily mileage of the WHCC vehicles is modest – around 16 miles per day – the data was interspersed with long cross-island trips from 150 to 200 miles. Although most of the routes driven by WHCC vehicles are suitable for EVs, cross-island trips are not – this suggests that a pooled fleet approach could help WHCC maximize their vehicle utilization while reducing fuel consumption.

Figure 5 compares the daily WHCC GPS travel survey mileage to the Hawaii county travel spread. According to available data, WHCC vehicles drive fewer miles than the Hawaii County average. For example, the median SUV in the WHCC fleet drives 40 miles per day, compared to 50 miles for the aggregate Hawaii County fleet. However, WHCC's passenger cars typically drive more than the Hawaii County average, likely due to trips made across the island to Hilo during the GPS survey. The mileage distribution shows that over 70% of WHCC fleet vehicle would be eligible for electrification with EVs, allowing WHCC to contribute to the greater island's petroleum reduction goals.



Time: 2hr 9min Distance: 147.6km
Moving Time: 1hr 54min Stopped Time: 14min
Max Speed: 116km/h Average Speed: 68km/h
Total Ascent: 2532 m Total Descent: 2459 m

Ready

Latitude: 19°23'29"N ☐ Longitude: 155°12'58"W

Figure 6.Sample of a GPS travel profile

Figure 6 shows a sample of the GPS route data, which yields spatial information about how WHCC vehicles are used. The left pane displays the GPS points on a map; the right pane plots speed and altitude profiles of the drive cycle. From here, the data is scrubbed to remove GPS drop-outs and artifacts generated by the loggers during operation.

WHCC vehicles were geographically contained to trips in the Kailua-Kona area, with only a few exceptions. This is consistent with the missions of the fleet, which primarily serve the smaller, western side of the island. As explained in the summary, a pure EV would not be a suitable candidate to travel over the saddle across the island, and so a plug-in hybrid (PHEV) would be a more suitable replacement for vehicles driving this route. Fast-chargers and battery-swap stations would open up a cross-island route to pure EVs.

Energy Usage and Solar PV at West Hawaii Civic Center

Photovoltaic (PV) solar panels are a useful tool in sustainable developments. PV converts solar energy to electrical energy silently, and at increasing efficiencies. Many commercial and public buildings/campuses consume energy during daytime hours while the sun is shining; this correlation makes solar PV an ideal power production technology when paired with a public or commercial facility like WHCC. The solar canopy generates renewable power for WHCC while providing share for cars parked on the top level.

At mid-day, the array provides double the peak power consumption of the building – over 100 kW is sent back to the grid in the current configuration. The data in Figure 7 shows the alignment of the solar power production with the WHCC load profile.

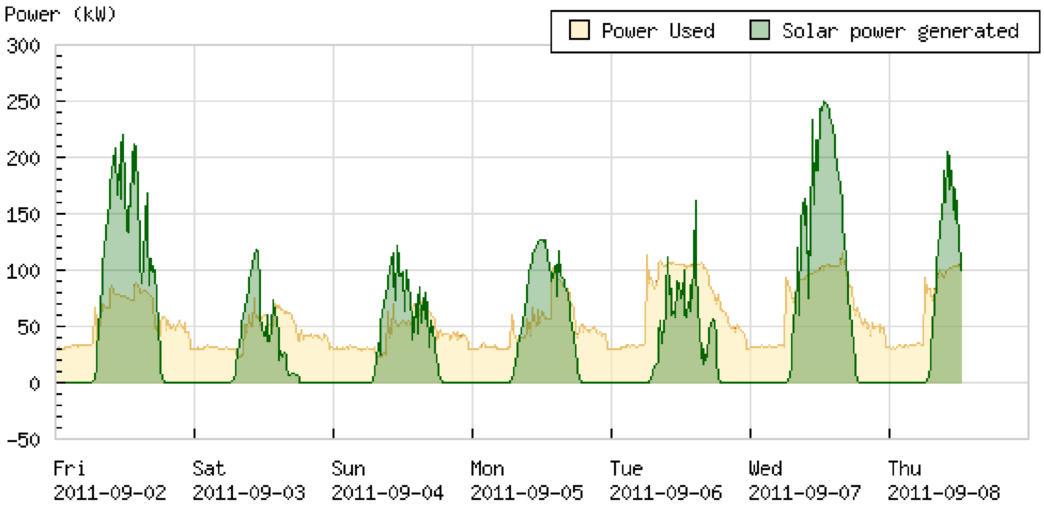


Figure 7: Facility Demand and PV Generation Profiles, sample from early September 2011

Baseline Power Use and Energy Costs – No Solar PV

The baseline power consumption for WHCC was measured for the months of July, August, and September. The power consumption data for these months will be generalized for the whole year, since Hawaii lies within the tropics and therefore exhibits minimal seasonal weather variability, the primary driver for commercial building energy use.

Table 4 summarizes energy usage characteristics for the period between July and September 2011. WHCC's energy use varied less than 10% over the 3 months analyzed. A higher demand factor was observed in September – the monthly demand factor is the ratio of average load to peak load, and a higher demand factor indicates a flatter load profile. The model calculated an average electricity price of 36.4¢/kWh, slightly higher than an average "J" schedule HELCO rate of 32.3¢/kWh[4].

Table 4. Energy usage and estimated bills for WHCC

Month	Energy kWh	Peak kW	Demand Factor	Weekday kWh avg	Weekend kWh avg	Monthly Bill (Estimated)	Effective Rate ¢/kWh
July	42800	141	41%	1590	1000	$15600	36.5
August	46300	151	41%	1680	960	$16900	36.5
September	45800	136	47%	1730	950	$16600	36.2

Current Power Use and Energy Costs – SunRun Solar PV

Before the installation of a distributed PV system, it should be stressed that the most cost-effective way to reduce energy bills is through efficiency. The West Hawaii Civic Center is a certified LEED Gold building, which means that major energy-saving features were implemented, such as natural day lighting and efficient air conditioning.

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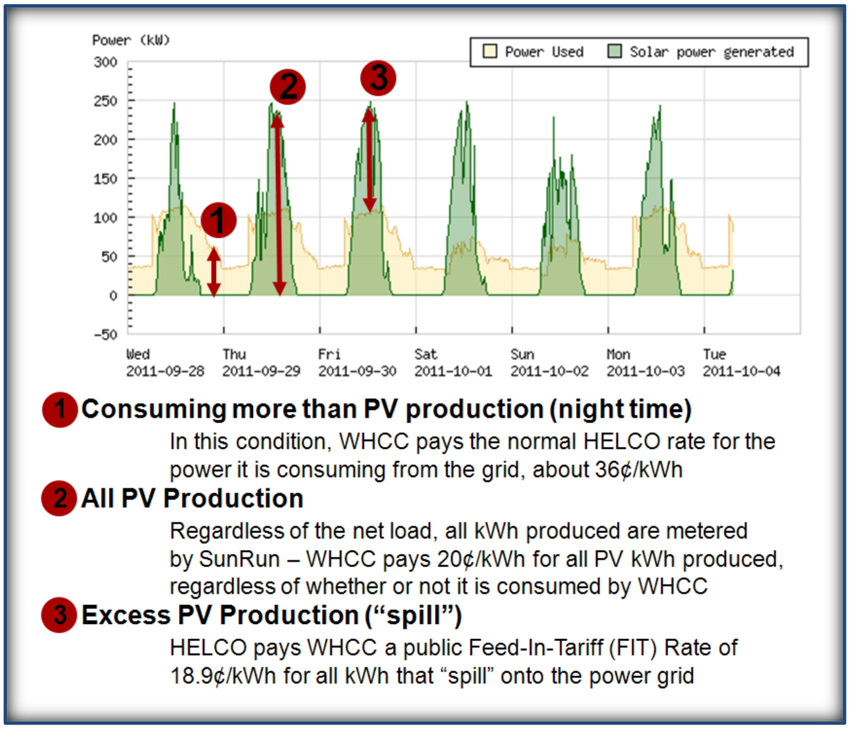
[4] Average Electric Rates for Hawaiian Electric Co., Maui Electric Co. and Hawaii Electric Light Co. http://www.helcohi.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=692e5e658e0fc010VgnVCM1000008119fea9RCRD&vgnextchannel=2c65a51aaabd6110VgnVCM1000005c011bacRCRD&vgnextfmt=default&vgnextrefresh=1&level=0&ct=article



① Consuming more than PV production (night time)

In this condition, WHCC pays the normal HELCO rate for the power it is consuming from the grid, about 36¢/kWh

② All PV Production

Regardless of the net load, all kWh produced are metered by SunRun – WHCC pays 20¢/kWh for all PV kWh produced, regardless of whether or not it is consumed by WHCC

③ Excess PV Production ("spill")

HELCO pays WHCC a public Feed-In-Tariff (FIT) Rate of 18.9¢/kWh for all kWh that "spill" onto the power grid

Figure 8. Diagram of WHCC's current power metering arrangement

WHCC's 250kW PV system is owned by PV developer-financer SunRun Inc. As shown in Figure 8, power metering and billing is split into 3 parts. Part 1 consists of power consumed directly from HELCO. This typically occurs during the nighttime when power is not being produced by WHCC's PV system. Billing from HELCO works as it normally would, where the energy price is determined by the kWh consumed and the peak load magnitude for that month. Part 2 of the billing is the solar production – SunRun bills WHCC for all kWh produced, regardless of whether or not WHCC consumes all of the power. SunRun charges a rate of 20¢/kWh. In the case where the PV array is producing more power than it is consuming, it "spills" onto the power grid (part 3). HELCO purchases spilled power from WHCC through a feed-in-tariff (FIT). WHCC is on a public-customer FIT rate of 18.9¢/kWh, thus WHCC is currently penalized under the current rate structure; WHCC ends up paying 1.1¢/kWh for excess PV power that it does not consume. Despite the penalty for overproducing, WHCC still ends up spending less on their monthly energy bills with the PV system, as shown in Table 5 and Table 6. In addition to the energy bill savings, greenhouse gas emissions are also reduced as oil-fired plants on the island are utilized less.

Table 5. WHCC Energy summary, including contributions from the 250kW PV array

Month	Energy kWh (Part 1)	Peak kW (Part 1)	PV Production kWh (Part 2)	PV Spill kWh (Part 3)	% Spilled
(July)	40000	141	4500	1640	36
August	23900	152	32500	10200	31
September	24400	136	31700	10300	33

Table 6. Estimated monthly bill summary under the current agreements with SunRun and HELCO

Month	Paid to HELCO	Paid to SunRun	FIT Income	Net Bill	% Bill Reduction	¢/kWh
(July)	$14670	$940	$310	$15300	1.9	35.7
August	$9440	$6750	$1920	$14270	15.6	30.8
September	$9450	$6590	$1960	$14080	15.2	30.7

Table 7. Estimated bill summary of the PV system under a commercial FIT rate

Month	Paid to HELCO	Paid to SunRun	FIT Income	Net Bill	Monthly Difference	¢/kWh
(July)	$14670	$940	$390	$15210	$90	35.5
August	$9440	$6750	$2440	$13750	$520	29.7
September	$9450	$6590	$2480	$13560	$520	29.6

Power Use and Energy Costs – Modified Tariff Structure Solar PV

If the WHCC were to be classified as a commercial customer, the economics of the PV system would be even more attractive; WHCC could be considered for the commercial customer FIT rate since the PV payments get routed directly to SunRun Inc. A summary of the economics under the 24¢/kWh FIT rate is summarized in

Table 7. The higher FIT rate would save WHCC $6200 annually, which could in turn be invested in WHCC's vehicle fleet. Opportunities for electrified vehicles t to utilize the excess PV will be summarized in the following sections.

Sustainable Transportation Systems Concept

Overview of Electric Vehicles

Advances in electric-drive technology has enabled commercialization of hybrid electric vehicles (HEVs), which integrate an internal combustion engine (ICE) with batteries, regenerative braking, and an electric motor to boost fuel economy. Continued technological advances have spawned plug-in HEVs (PHEVs), which integrate small ICEs and larger, grid-chargeable batteries that enable 10 to 40 miles of all-electric driving. Advanced technologies have also enabled manufacturers to introduce a new breed of all-electric vehicles (EVs) that don't use an ICE at all, and therefore burn zero petroleum.

Today's PEVs are state-of-the-art highway vehicles able to match or surpass the performance of their conventional gasoline and diesel counterparts. However, some medium- and heavy-duty electric vehicles have a limited maximum speed (e.g., 50 to 75 miles per hour) appropriate to their vocation. In addition, PEVs in all-electric mode are much quieter than conventional vehicles and, unlike conventional vehicles, produce maximum torque and smooth acceleration from a full stop. This low-end torque can be especially useful when hauling heavy loads. This instant torque is the reason locomotives use electric motors, powered by diesel ICE generators, to cover long distances.

Currently, only a few light-duty PEVs are commercially available. PEV technology is only beginning to make inroads into the U.S. vehicle market, but the number of available vehicles is predicted to grow quickly. For comparison, only two HEV models were available in the late 1990s compared with 29 models today.[5] A larger number of medium- and heavy-duty PEV models are currently available, most of which are EVs. Applications include delivery trucks, step vans, transit and shuttle buses, and utility trucks.[6]

In addition to limited availability of PEV models, early PEV introductions (starting in 2010) have been limited to select geographic areas to match dealer and service preparation. Fortunately, Hawaii has been included in the first wave for several PEV rollouts.

Example Light-Duty PEV Prices, 2011[1]

Chevy Volt (PHEV)	$40,280
Nissan Leaf (EV)	$32,780
Plugin Prius (PHEV)	$32,000

Example Medium- and Heavy-Duty PEV Prices, 2011

Ford Transit Connect EV (Class 3 van)[2]	$57,400
Navistar eStar (Class 3 van)[3]	$150,000
SEV Newton (Class 5 vocational truck)[4]	$123,600
ZeroTruck (Class 5 van/vocational truck)[4]	$155,500

[1] MSRP, before incentives.
[2] As reported in the New York Times, December 7, 2010, “Ford Starts to Ship an Electric Delivery Van.”
[3] As reported in Autoblog Green, May 15, 2010.
[4] As reported in the U.S. General Services Administration (GSA) *2011 Model Year Alternative Fuel Vehicle Guide*. Note that GSA prices may not be available to non-GSA-supported fleets.

Prices and Incentives

Purchase prices for today’s PEVs are considerably higher than for similar conventional vehicles, although prices are likely to decrease as production volumes increase. Fleets recoup some PEV purchase costs through lower operating costs and government incentives.

The federal Qualified Plug-In Electric Drive Motor Vehicle Tax Credit is available for PEV purchases through 2014 (or until PEV manufacturers meet a certain level of mass production). It provides a tax credit of $2,500 to $7,500 for new PEV purchases, with the specific credit amount determined by the size of the vehicle and the capacity of its battery. It is limited to vehicles with a gross vehicle weight rating up to 14,000 pounds. Currently, all of the available light-duty PEVs qualify for a $7,500 credit. Some of the available medium-duty EVs also qualify for a credit.

Hawaii currently offers rebates of up to 20% of the vehicle purchase price (up to $4,500) through the Hawaii EV Ready Rebate Program.[7]

Overview of Electric Vehicle Infrastructure

Charger – On-board/Off-board

The power electronics for charging the energy storage system may be on-board or off-board the vehicle. Onboard units take AC power from the grid and rectify it to DC power to charge the DC battery pack. Off-board units make this same conversion and deliver DC power to the vehicle. Communication between the battery management system and the charger must occur to ensure energy is delivered safely. Power-quality standards for chargers are being developed with the goal of minimizing impacts to local power quality.

Vehicle charging infrastructure also offers the opportunity to reverse power flow from the vehicle battery to the grid. The value of this scenario must be balanced with driver needs, power conversion efficiency losses, and battery-life impacts. Chargers and associated cords are categorized by voltage and power levels, shown in Table 8. The value of each charge power level is tied directly to the size of the on-board battery pack and the time available for recharging.

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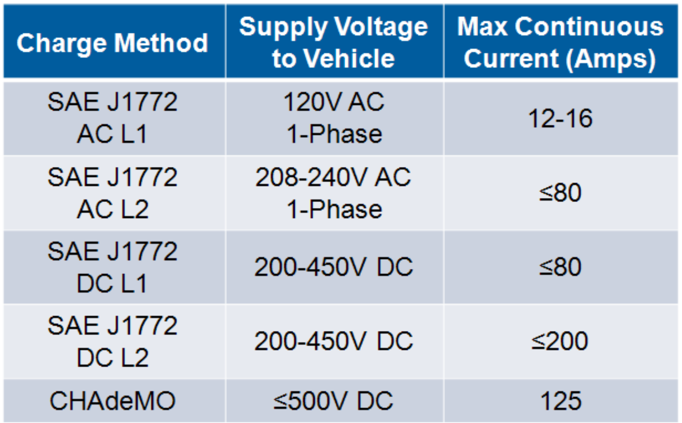
[5] To find currently available PEVs, use the AFDC Light-Duty Vehicle Search (www.afdc.energy.gov/afdc/vehicles/search/light).
[6] To find currently available medium- and heavy-duty PEVs, use the AFDC Heavy-Duty Vehicle and Engine Search (www.afdc.energy.gov/afdc/vehicles/search/heavy).
[7] http://hawaii.gov/dbedt/info/energy/evrebatesgrants/rebates

Table 8. Charging specification for current vehicle standards



Charge Method	Supply Voltage to Vehicle	Max Continuous Current (Amps)
SAE J1772 AC L1	120V AC 1-Phase	12-16
SAE J1772 AC L2	208-240V AC 1-Phase	≤80
SAE J1772 DC L1	200-450V DC	≤80
SAE J1772 DC L2	200-450V DC	≤200
CHAdeMO	≤500V DC	125

Electric Vehicle Supply Equipment

Electric vehicle supply equipment (EVSE) improves the safety of vehicle charging in accordance with the National Electric Code. The EVSE enables power flow between the electricity distribution system and the PEV only when a cord and connector have made a secure connection. For Level II charging, the cord is permanently attached to the EVSE and is de-energized when not connected to the vehicle inlet. The EVSE and charger may be a single component if the charger is located off-board the vehicle. In some regions, the EVSE will be connected to or include a sub-meter for measuring electricity delivered to the vehicle, separate from electricity delivered to the rest of the premises. This feature supports low-carbon fuel standard accounting.

Cords and Connectors

In the previous generation of EVs, cords and connectors became a point of debate. Today, SAE has led efforts to standardize a connector for conductive charging in the United States. The SAE J1772 standard defines a five-pin configuration that will be used for Level I and Level II charging. A Level III connector and the use of the current connector for DC power flow are under development. Tripping hazards and ADA compliance due to cords in garage areas and public places may be a safety and adoption hurdle, thus EVSEs supporting wireless inductive charging and retractable cord systems are currently under development[8][9]. The installation of an EVSE in a building may also present a hurdle to adoption because it involves multiple parties, including utilities, building inspectors, electricians, and vendors.[10]

Advanced Meters

Investment by utilities and governments in smart-grid technology supports the improvement of utility operations. Advanced meters are likely to be the primary access point for utilities to gather information on consumer use and transmit information to consumers to alter their behavior. Advanced meters are not required to enable vehicle charging or charge management. However, future PEVs may be the most significant configurable load accessed by advanced meters.

Vehicle-to-Grid and Communication Standards

The standard proposal for communication between plug-in vehicles and the utility grid is specified in SAE J2847/1 – it encompasses messages between plug-in vehicles and the utility grid for energy request/response, load control/demand response, pricing, timing information, and vehicle

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[8] Plugless Power. www.pluglesspower.com

[9] EVSE LLC, http://evse.controlmod.com/

[10] “Electric Vehicle Charging Infrastructure Deployment Guidelines British Columbia.” BC Hydro. July 2009.

information/charging status. Although all the messaging defined in J2847/1 is between PEVs and the utility grid, EVSEs can access all transmitted messages. J2847/1 is still under development and no EVSE currently in the market supports this standard.

Most EVSEs for AC charging support SAE J1772, but does not conduct communication with the plug-in vehicle. Many AC charging stations in the market today are equipped with wireless communication devices such as ZigBee or cellular network devices. However, these devices are being used for communication between charging stations or between the charging station and smart phones, and they are not intended for the communication with the PEV.

For fast DC charging, CHAdeMO is most widely used specification, and there are many plug-in vehicles and EVSEs that support it. The CHAdeMO charger uses a digital communication via CAN. Information transmitted via CAN include parameters like maximum battery voltage, target battery voltage, energy capacity available, and maximum charging current.

SAE is currently developing standards for fast DC charging. Communication between plug-in vehicles and off-board DC chargers is proposed in J2847/2. For the vehicle inlet and connector for fast DC charging, a “combo” coupler has been proposed in order to support present J1772 AC charging. It also supports J1772 AC vehicle inlet, as shown in Figure 9.

Figure 9: The SAE Vehicle Inlet and Connector for DC Charging (left); J1772 Inlet (center); layout of CHAdeMO connector (right). The part circled in red (left) is the port for DC power delivery on the J1772 connector

WHCC Total Fuel & Energy Costs with Vehicle Electrification

The following analysis will combine building usage data with fleet usage data to assess WHCC’s overall vehicle fuel and building energy expenditures. It is our goal to demonstrate how to minimize WHCC’s petroleum consumption and decrease energy costs. Although the initial investment to electrify WHCC’s fleet could be significant, the long-term environmental and cost benefits to the Hawaiian people make WHCC fleet electrification *pono*.

Opportunity Charging & Consuming Excess Solar PV

NREL calculated load profiles for the West Hawaii Civic Center based on the GPS travel survey data, shown in Figure 10. NREL assumed 3 current PEV offerings that would be likely candidates for WHCC vehicle replacement: the Chevy Volt, Nissan Leaf, and Plugin Prius. Charging rate was varied between 3.3 kW and 6.6 kW, and daytime opportunity charging vs. night-only charging was compared. Because the GPS survey data represented a very low bound on daily miles traveled, the data was scaled 3x to more closely match the mileage travelled by the greater public Hawaii vehicle fleet. Average mileage was 48 miles/day, compared to the overall Hawaii fleet vehicle average of 66 miles/day.

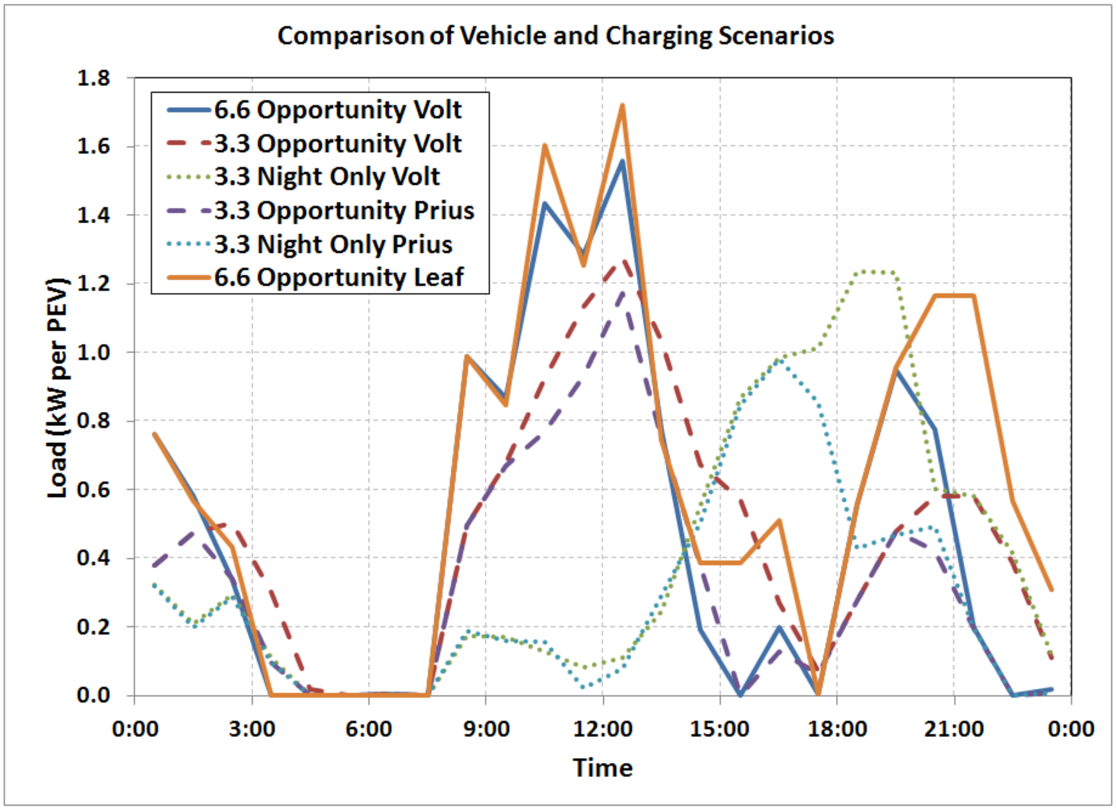

Figure 10. Comparison of charging scenarios for WHCC, based on GPS travel profile data

The largest peak in vehicle arrivals coincides nicely with PV power production, and therefore NREL specifically recommends opportunity charging vehicles at the WHCC, rather than waiting until night-time. Because Hawaii's grid is comprised of more flexible generators than most places, off-peak power is not incentivized as is often the case on the mainland.

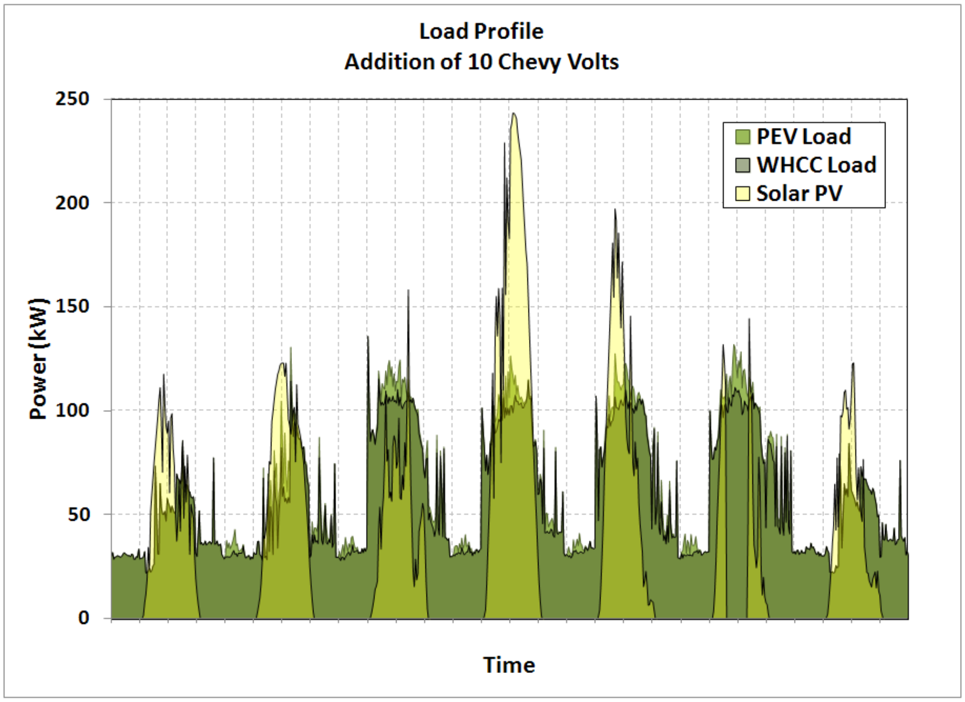

Figure 11. Example load profile for the week of September 4, 2011 with the additional load of 10 Chevy Volts. This scenario assumes 3.3 kW opportunity charging.

To calculate the cost of energy to charge the PEV fleet, the simulated vehicle loads were added on top of the existing building load – an example load profile of 10 Chevy Volts charging at WHCC is shown in Figure 11. The simulation results are summarized in Figure 12. Assuming weekday mileage of 45 miles, the Volt and Leaf were able to accomplish their routine daily missions without consuming any fuel, while the Prius consumed less than 7 gallons per month; their total operating costs were on nearly identical, at around $90/month. The monthly cost-of-operation was considerably less than the conventional vehicles – on average, the plug-in vehicles saved between $130 and $190 per month, or $1600 to $2300 annually.

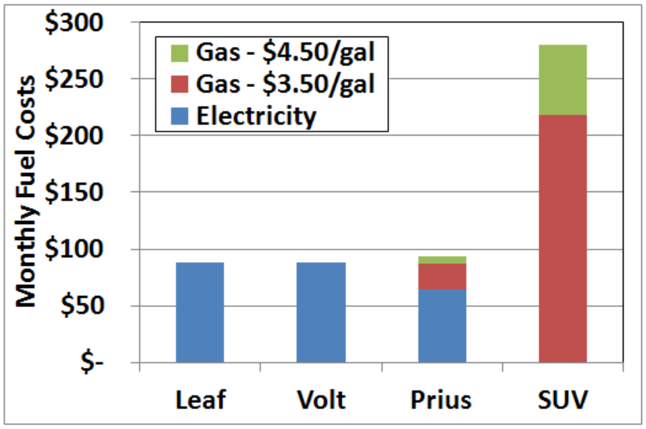

Figure 12. Monthly fuel costs for selected vehicles at WHCC, based on typical driving behavior

Additionally, the lower maintenance cost of pure EVs was not considered here – because electric vehicles have fewer moving parts, they require significantly less maintenance. These factors should also be considered into the lifetime cost – these factors were beyond the scope of the current analysis.

GPS Travel Survey – EV Infrastructure Across Big Island

WHCC vehicles sometimes travel to the other center of government on the island in Hilo. Given current offerings for pure EVs, the Kona-Hilo trip would not be possible unless infrastructure were available along the route[11]. Infrastructure for fast-charging electric vehicles is continuously coming down in cost[12]. Because battery technology is the most expensive component of new PEVs on the market, driving range is smaller than conventionally fueled vehicles.

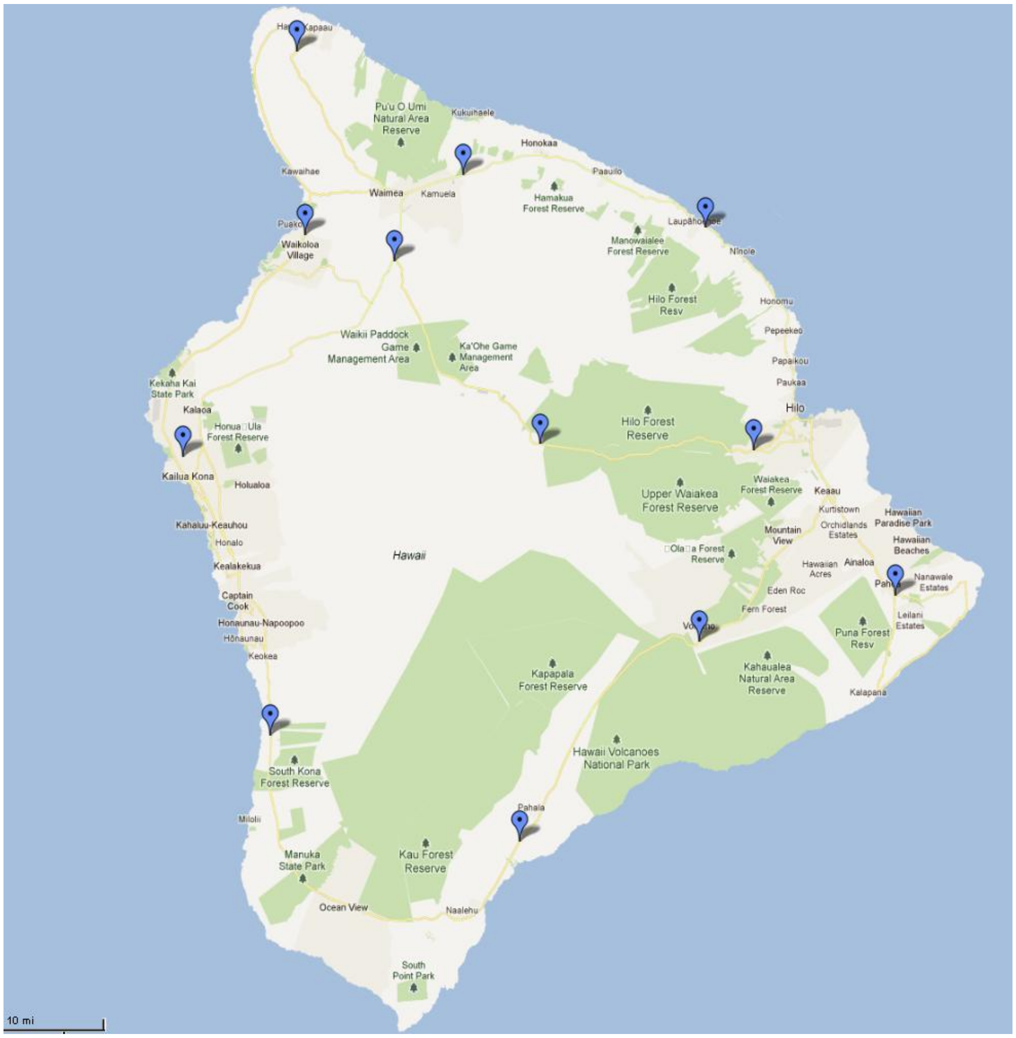

Figure 13. Map of the big island showing the number of fast chargers that would be required to meet roughly 30-mile coverage along Hawaiian highways

Figure 13 indicates 30-mile coverage along the highways of big island, particularly along the saddle road route between Kailua-Kona and Hilo. The map shown is shown as an example only; power infrastructure availability, land use permitting, and other external factors would need to be considered in a more detailed study.

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[11] http://wot.motortrend.com/realworld-results-2011-nissan-leaf-ev-range-may-differ-by-40-miles-8067.html

[12] http://www.newsauto.pl/index.php/archives/1304?lang=en

Maximizing WHCC's PV Return-On-Investment

Electricity from WHCC's 250kW solar array is considerably cheaper than gasoline on a per-mile basis. The 6-year lifetime fuel costs of available PEVs were compared to a conventional SUV. The SUV assumed in this analysis was an entry-level Chevy Equinox. The cost escalation rate of electricity was calculated to be 1.62% per year, from WHCC's electricity cost analysis. Gasoline escalation costs were based on a global crude oil 10-year price horizon[13], starting at $4.50 per gallon. Although outright vehicle purchase prices were assumed for this analysis, vehicle leasing is another option that could potentially reduce the capital costs associated with putting new vehicles into service.

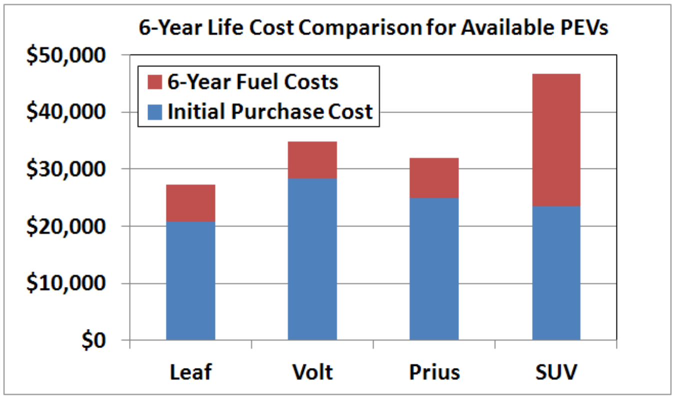

Figure 14. Estimated ownership costs of 4 types of vehicles

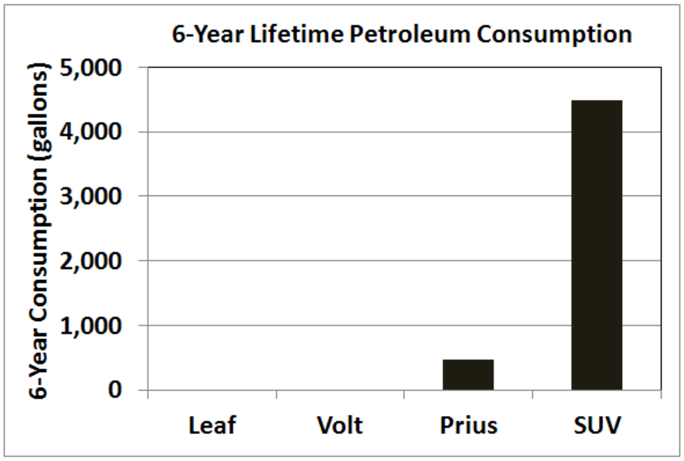

Figure 15. Petroleum consumption over 6 years for WHCC vehicles based on driving behavior. This analysis assumes daytime opportunity charging is available.

The 6-year life cost of the Nissan Leaf was the lowest overall, assuming the vehicle being replaced is not needed for cross-island travel. For vehicles conducting occasional cross-island travel, the Prius cost $3000 less than the Volt over 6 years. However, the Volt consumes less gasoline than the Prius based on typical WHCC drive cycles – the tradeoff being outright petroleum reduction versus overall cost reduction. Figure 15 compares the 6-year fuel consumption of vehicles current serving WHCC to PEVs available to replace those vehicles.

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[13] http://205.254.135.24/emeu/international/oilprice.html

Opportunity charging the vehicles during the daytime gives WHCC the opportunity to help the island and state meet its clean energy goals by powering its vehicles with clean, local, renewably generated electricity. According to previous analysis by WHCC, $120,000 in electricity costs should be saved by operating the PV array each year. Part of those cost savings could be used to make the capital investments in cleaner plug-in vehicles, which will save WHCC even more money in the long-term. Converting just 25% of WHCC's vehicle fleet to plug-in vehicle could potentially save WHCC $130,000 in fuel costs alone over 6 years.

Future Vision – 90% Petroleum Reduction for WHCC Fleet

In order to meet the ambitious goals of a completely clean-energy future, WHCC must make significant investment in electrified vehicle – we propose a long-term future vision where 38 out of 42 vehicles would be replaced with an electric alternative. With the 250 kW solar array as part of the new LEED-gold facility, WHCC is already a "living laboratory" for clean energy implementation. A huge variety of fuel-saving technologies and operating practices could be part of WHCC's overall clean-energy plan. A recent trend in populated metro areas utilized a pooled vehicle fleet approach like eGo, Carshare, ZipCar, or I-GO, among many others. Additionally, WHCC's shuttle busses could be replaced with a commercially available medium-duty or heavy-duty vehicle. The use of advanced energy storage systems should be analyzed to determine possible savings to WHCC by reducing night-time energy consumption and utilizing excess solar production.

Conclusions

West Hawaii Civic Center is a living laboratory that sets a high standard for sustainable development. NREL's analysis of WHCC's vehicle fleet shows significant potential for daytime opportunity charging of electric vehicles, utilizing the excess capacity of their 250 kW PV array. Based on previous analysis, some of the $130,000 annual savings from the solar array could be used as capital for electric vehicles, which would save WHCC over $1600 per vehicle each year, in additional to helping Hawaii meet its ambitious petroleum reduction goals. Energy independence on Big Island would save Hawaii money and is achievable with today's technology, in addition to benefits to the environment and local economy. NREL recommends the following specific steps for West Hawaii Civic Center:

1) Choose PEV replacements for vehicles eligible and ready to be turned over
2) Utilize excess solar PV capacity by moving flexible loads to mid-day, when excess PV power is available
3) Lower overnight loads where possible
4) Continue collaboration with NREL to understand the infrastructure requirements and costs associated with cross-island travel using pure EVs