



# Hawai'i's EVolution

Hawai'i Powered. Technology Driven.



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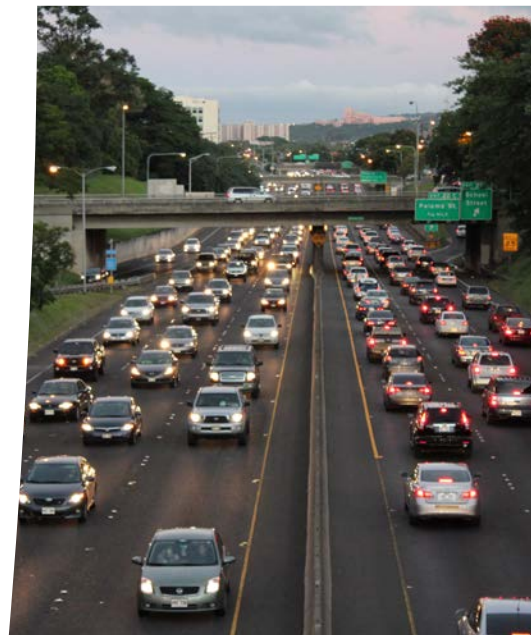
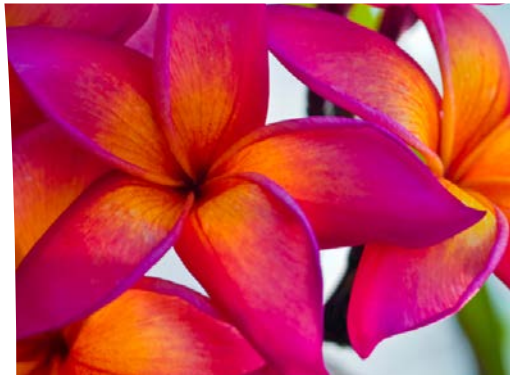
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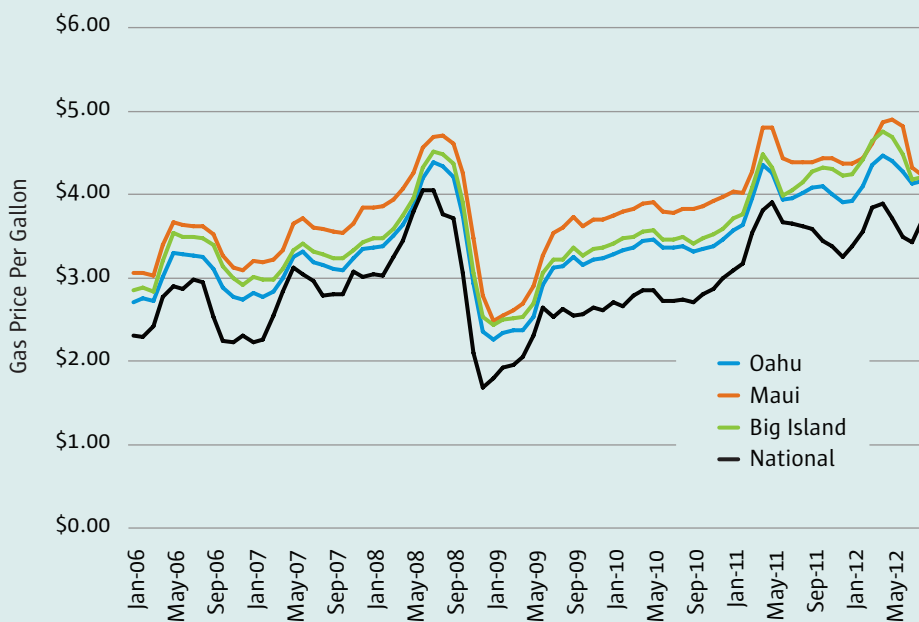


In July 2008, the price of oil in Hawai‘i soared to nearly \$150 per barrel and gas prices first surpassed \$4 per gallon. For a state nearly 100% dependent on imported petroleum to meet its energy needs, both the opportunity and need to invest in and implement clean energy technologies was apparent. One technology the state identified that could help alleviate some of the “pain at the pump” was the electric vehicle (EV), along with the associated infrastructure. In the years that have followed, statewide average gas prices have risen steadily and have remained above \$4 per gallon since March 2011, at times hitting \$5 per gallon. At these prices, Hawai‘i drivers can pay as much as \$2,000 or more annually for gasoline — a good incentive for embracing EVs.

### Charting the Course Toward a Clean Energy Future

Partnering with the U.S. Department of Energy (DOE), the state launched the Hawai‘i Clean Energy Initiative (HCEI) in January 2008, with a long-term goal of achieving 70% clean energy by 2030. Since then, Hawai‘i has taken a leadership role in transitioning to a clean energy economy driven by technology innovation and powered by indigenous sources of energy.

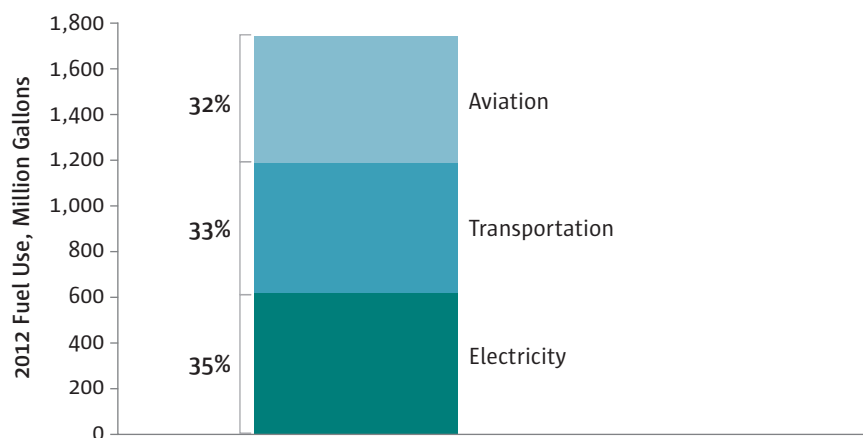
Hawai‘i Gas Prices by Island



Hawai‘i gas prices by island for a gasoline-powered vehicle

Source: Hawai‘i Department of Business, Economic Development, and Tourism (DBEDT). *Graphic by Stacy Buchanan, NREL*

### Liquid Fuel Use in Hawai'i



Like many places in the world, Hawai'i relies on transportation to drive its economy. Transportation is used to get people from work and school, move more than 7 million tourists per year, and deliver goods and services. Ground transportation also plays an important role in the public service sector and is an indispensable element of the U.S. military's daily operations. According to DBEDT, 65% of Hawai'i's liquid fossil fuel use is for transportation; ground transportation represents more than half of that. *Source: DBEDT. Graphic by Stacy Buchanan, NREL*

The state's clean energy goal is the most aggressive in the nation. Its groundbreaking renewable energy and energy efficiency portfolio standards have set a bold example for other states and territories. And its advances on the clean energy front have positioned it as a worldwide leader in charting the course toward a clean energy future.

### Forging a New Path for Island Transportation

In addition to making significant strides in renewable energy development and building energy efficiency, Hawai'i is forging a new path for island transportation. Over the past four years (building on work done since the 1990s), it has adopted alternative vehicle technologies and deployed associated energy infrastructure at an accelerated pace and scale. Along with solar, wind, and biomass technologies and energy efficiency improvements,

EVs have become a driving force in Hawai'i's energy transformation.

In 2011 approximately 1% of vehicles sold in Hawai'i were EVs, which far exceeded the national average of approximately 0.1%, and within a year Hawai'i led the nation in available EV charging infrastructure per capita, positioning the state at the forefront of an evolving U.S. auto market.

Hawai'i's unique combination of energy challenges and opportunities make it an ideal place to showcase the technical and economic viability of EVs. Because of its geographic isolation, Hawai'i has the highest gasoline prices in the nation. And as an island state, it is especially vulnerable to the environmental impacts of carbon emissions. On the other hand, its abundance of renewable resources, mild climate, limited driving distances, constant influx of tourists, and political will to change make Hawai'i an excellent location for EVs.

### Creating a Sustainable Transportation Sector

To address the economic and environmental challenges associated with relying on imported oil for transportation and to help meet HCEI's 70% clean energy goal, the HCEI Transportation Working Group's mission is to help Hawai'i reduce petroleum used for ground transportation 70% by 2030. The interdisciplinary group helps to steer the direction of transportation in Hawai'i through four strategic approaches:

- Improve the standard vehicle efficiency of the fleet
- Reduce the overall number of vehicle miles traveled
- Expand the use of renewable fuels in the transportation sector
- Accelerate the deployment of electric and hydrogen vehicles and related infrastructure

The long-term vision is to create a clean, sustainable transportation sector that integrates state-of-the-art alternative vehicle technologies with a full range of renewable energy systems and infrastructure to create a clean energy economy that serves as a replicable model for other island communities. Among the near-term pathways the working group is encouraging for EVs are:

- Completing the development of an EV charging network and related infrastructure
- Providing incentives for early adopters for both EVs and charging equipment
- Collaborating with the automotive industry to continue to increase EV market penetration — in quantity and vehicle variety — while maintaining industry support and investment

## HCEI Transportation Working Group

### Members

Co-Chair: Margaret Larson, DBEDT – State Energy Office

Co-Chair: Ken Kelly, National Renewable Energy Laboratory (NREL)

AeroVironment

Alliance of Automobile Manufacturers

Aloha Petroleum

Better Place

City & County of Honolulu – Department of Facility Maintenance

Enterprise Holdings\*

Environmental Protection Agency

Hawai'i Automobile Dealers Association\*

Hawai'i Center for Advanced Transportation Technologies

Hawai'i, Honolulu, Maui, and Kaua'i County Energy Coordinators

Hawai'i Natural Energy Institute (HNEI)

Hawai'i Renewable Energy Development Venture

Hawai'i State Department of Accounting and General Services – Automotive Management Division

Hawai'i State Department of Transportation – Highways Division

Hawaiian Electric Company (HECO)\*

Honolulu Clean Cities

Kauai Island Utility Cooperative

National Car Rental

Oahu Metropolitan Planning Organization

United States Pacific Command

University of Hawai'i at Manoa – Department of Urban and Regional Planning

- Monitoring and refining incentive structures for different types of EVs
- Integrating EVs with energy distribution

Moving full-throttle ahead toward the 70% goal, HCEI is not only revolutionizing transportation in Hawai'i, it is a committed early adopter of advanced vehicle alternatives and is on the leading edge of a transportation tipping point.

### Embracing New Alternatives

Today, there are more advanced vehicle alternatives on the market than ever before, and the list is growing. Many of the available options have some form of electric drive system, including hybrid electric vehicles (HEVs) and fuel cell vehicles, plug-in HEVs (PHEVs), and all-EVs.

Employing state-of-the-art technology and design, HEVs, PHEVs, and EVs outperform traditional gasoline- and diesel-fueled vehicles in fuel economy and emissions. As the technologies improve, alternative fuel vehicles are becoming cost-competitive with traditional vehicles. Even with Hawai'i's high cost of electricity, the higher efficiencies of EVs still make them cost-effective. And, when combined with renewable energy, the potential economic advantage is even greater.

### Hawai'i Emerges as a Leading Market for EVs

In 2011, Pike Research ranked Hawai'i as the top state in the country for EV penetration. Forecasting a 43% compound annual growth rate over a six-year period, the report estimated EVs will make up 6.7% of the Hawai'i auto market by 2017, when yearly sales will reach nearly 360,000

nationally.<sup>1</sup> As HCEI approaches the 5-year mark, the state is well positioned to rise to the occasion. At the end of 2012 there were 1,136 EVs on Hawai'i's roads. And with nearly 290 charging ports—one for every 5,000 residents—installed throughout the islands, Hawai'i leads the nation in EV charging ability per capita.<sup>2</sup>

With average gas prices at \$4.00/gallon in Hawai'i, the cost to drive an EV is typically lower than operating a similar gasoline-fueled vehicle.<sup>3</sup> And with Hawai'i's off-peak electricity rates, EV drivers gain an even greater cost advantage for charging their vehicles when demand is lower. According to HECO, more than one-third of EV owners are taking advantage of the time-of-use pricing it offers to encourage overnight charging.<sup>4</sup>

The continuous influx of tourists in Hawai'i makes it a natural test bed for EVs. Manufacturers, rental agencies, hotels, and other businesses have the ability to showcase advanced vehicle technologies and related infrastructure under ideal conditions that are conducive to creating a positive experience for tourists. Visitors can carry that positive experience with EVs home when they leave the islands, helping promote the widespread acceptance of EVs. Combined with the unique advantages of the Hawai'i market, this creates a rich economic development opportunity.

1 "Electric Vehicle Geographic Forecasts." Pike Research. 2011. <http://www.pikeresearch.com/research/electric-vehicle-geographic-forecasts>.

2 Based on latest Hawai'i population estimates. <http://energy.hawaii.gov/programs/transportation-on-the-move/ev-ready-program>.

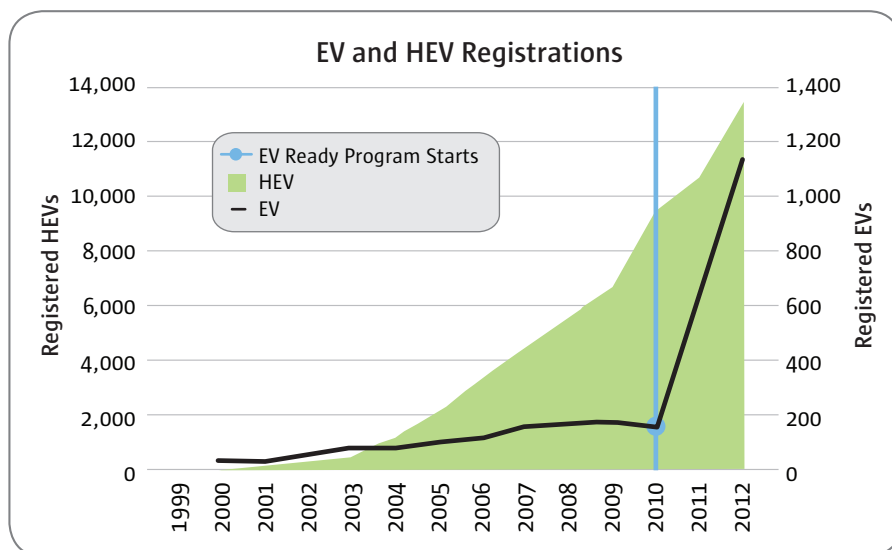
3 *Driving EVs Forward: A Case Study of the Market Introduction and Deployment of the EV in Hawaii*. DBEDT. 2012. <http://www.energy.hawaii.gov/wp-content/uploads/2011/09/EVReportMauiElectricVehicleAlliance2012.pdf>.

4 *Clean Energy Update: February 2012*. HECO, Maui Electric Company (MELCO), Hawaii Electric Light Company (HELCO). 2012. [http://hawaiisenergyfuture.com/Images/Clean\\_Energy\\_Update\\_Feb2012.pdf](http://hawaiisenergyfuture.com/Images/Clean_Energy_Update_Feb2012.pdf).

\*Highlighted in this brochure

## Overcoming EV Challenges in Hawai'i

| EV Challenges  | Responding to the Challenges  |
|--|---|
| <b>Range Anxiety:</b> Widely accessible charging infrastructure requires the development of a viable business model for property owners.               | Short island driving distances and established and growing Hawai'i charging infrastructure (including DC fast chargers) reduce range anxiety.   |
| <b>Battery Life:</b> Limitations on EV battery life-cycle increases perceived risk to consumers.   | Vehicle batteries are covered under warranty, e.g. 10 years/100,000 miles. The mild island climate is conducive to EV life, performance, and efficiency.  |
| <b>EV Prices:</b> The higher retail price of EVs compared to conventional vehicles may limit market penetration, especially if incentives are reduced. | National/international efforts are focused on reducing battery and EV cost. Financial and other incentives help offset higher EV purchase prices.   |
| <b>Limited Market:</b> The limited population and remoteness of Hawai'i make the market less attractive to manufacturers.                              | Local efforts to establish Hawai'i "EV-friendly" policies, infrastructure, and business environment have resulted in early market EV rollouts.  |
| <b>Grid Impacts:</b> Increased EV penetration may impact grid reliability due to increased load and load concentration.                                | Utility, industry, and research organizations are working to ensure the grid can accommodate EV load requirements. Integration of EVs with smart grid technology may help manage EV impacts.  |
| <b>Cost of Electricity:</b> Sites with high electricity loads may see increased electricity costs and demand charges to provide EV charging.           | Net metering and time-of-use rates provide incentives to integrate EVs with other renewable energy technologies at homes and businesses. The utilities are evaluating demand charge alternatives for EV fast charging sites. The high cost of gasoline combined with the use of renewable electricity yield favorable EV operational costs. |



Source: DBEDT. Graphic by Christina Chase, NREL

## Breaking Through Barriers

Despite its ripe environment for transitioning to clean transportation, Hawai'i has had to overcome significant challenges in seeking to fast-track the adoption of EVs on the islands. These included reducing range anxiety, or fear of being stranded on empty with no way to recharge one's vehicle; the higher retail price of EVs compared to conventional vehicles; and a relatively small population that makes it difficult for Hawai'i to compete with larger markets. Among the tactics Hawai'i has adopted to tackle these issues aggressively are financial incentives and regulatory changes.

### Financial Incentives

Federal, state, and private dollars have funded a number of EV deployment programs in Hawai'i, including:

- **\$4.5 million in federal stimulus funding** provided by DOE's State Energy Program through the Recovery Act for the EV Ready Program (EV Ready). EV Ready awarded six grants for public charging infrastructure and provided more than 700 rebates to Hawai'i residents and businesses that purchased EVs and installed charging equipment.
- **Nearly \$300,000 in DOE funding** awarded to the University of Hawai'i Maui College in partnership with the Hawai'i State Energy Office, the Honolulu Clean Cities Coalition, and the University of California San Diego. Together, grant partners have developed a comprehensive plan that addresses the deployment of EVs and charging infrastructure, through an EV charging permitting process, policies, incentives, and a renewable energy grid system analysis.

## Test Drive: Enterprise Rent-A-Car

More than 7 million tourists visit Hawai'i annually, and many of them rent cars. Because Hawai'i is such an ideal location for EVs, the introduction of EVs into the Hawaiian rental car market provides an opportunity for consumers to experience driving an EV without actually purchasing one. The first rental car company in Hawai'i to install charging stations and offer EVs to its customers, Enterprise Rent-A-Car now has 20 EVs and three charging stations in its Oahu fleet. Charging stations for Enterprise's EVs are available via the network that was funded by the EV Ready Program. As of this printing, there are 10 chargers with a total of 12 ports available at four Hawai'i Enterprise Rent-A-Car locations, and more are planned.

"We at Enterprise are very excited to offer our community and visitors the opportunity to rent EVs. Initially, we will be renting our EVs at our airport location because this is where we have our charging stations. However, we plan to expand the locations that offer EVs to many of our 29 neighborhood, resort, and airport branch locations in order to meet the growing needs of EV renters," said Paul Kopel, vice president and general manager of operations for Enterprise Holdings in Hawai'i. "What's great is that our local customers will be able to experience the future of transportation by test driving an EV at an affordable price."



An EV charging up at one of Hawai'i's three Enterprise Rent-A-Car charging stations.

Photo by Ken Kelly, NREL 24513

Along with federal funding made available to the state of Hawai'i to stimulate EV sales, federal tax credits of up to \$7,500 are available to Hawai'i EV buyers through the Recovery Act-funded Qualified Plug-in Electric Drive Motor Vehicle Credit (through 2014 or until manufacturers sell 200,000 vehicles).<sup>5</sup>

### Regulatory Changes

In addition to funding programs designed to advance EV deployment, the State of Hawai'i has collaborated with HCEI working groups, island utilities, the Public Utilities Commission, and the state legislature to enact a number of EV-friendly policies, including:

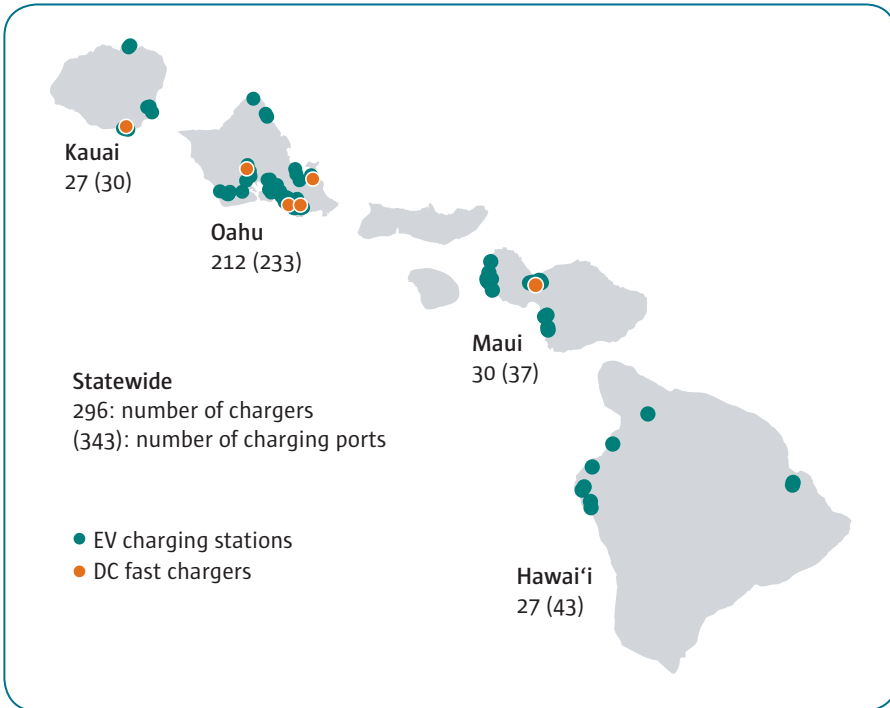
- **Designated EV Parking Requirement** – Act 156 [HRS 291-71](#) (2009 and amended by Act 89, 2012) requires large parking lots with more than 100 parking stalls available for public use to designate at least one parking space exclusively for electric vehicles and to be equipped with an electric vehicle charging system.
- **Leadership by Example** – Act 156 [HRS 291-71](#) also requires state and county government agencies to lead by example in selecting alternative vehicles, with EVs and PHEVs at the top of the prescribed hierarchy.

- **EV Charging Equipment Mandate for Homeowner Associations** – Act 186 [HRS 196-7.5](#) (2010) provides that homeowners can install an EV charging system on or near the parking stall of any multifamily residential dwelling or townhouse they own. While this law allows private entities to reasonably restrict the placement and use of charging systems, it prohibits them from banning their placement or use altogether.
- **EV Plates and Free Metered Parking** – Act 290 (1997), superseded by Act 168 (2012), allows vehicles with EV plates to use high-occupancy vehicle lanes regardless of the number of occupants and provides free metered parking to EVs at state and county locations.
- **EV Pilot Rates** – HECO offers EV pilot rates for both residential and commercial customers. Designed to encourage EV drivers to charge their vehicles during off-peak hours, the time-of-use discounts are available to customers on Oahu, Maui, and Hawai'i for charging highway-capable, four-wheeled EVs and PHEVs. The pilot will remain in effect until October 1, 2013.<sup>6</sup>

<sup>5</sup> Recovery Act phases out the credit for each manufacturer after they sell 200,000 vehicles. Internal Revenue Service. <http://www.irs.gov/uac/Going-Green-May-Reduce-Your-Taxes>.

<sup>6</sup> "Residential EV Pilot Rates." HECO. <http://www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnnextoid=6c4eb8d886136310VgnVCM1000005041aacRCD&cpsextrchannel=1>.





Locations of EV charging stations and DC fast chargers in Hawai'i as of February 2013.  
Illustration by Stacy Buchanan, NREL

## Expanded EV Charging Station Options

The combination of financial incentives and EV-friendly policies is having a domino effect on the Hawai'i market: as EV sales continue to rise, the network of available EV supply equipment (EVSE) expands and improves. In turn, as charging convenience increases, EV sales will likely see even sharper increases. In July 2012 Aloha Petroleum installed the first public DC fast chargers at Hawai'i gas stations, marking another milestone in EV charging convenience on the islands. There are

now three different levels of charging available to Hawai'i EV owners:

- 1) **Level 1** – charges via a 120-volt (V) outlet, such as standard household outlets; adds approximately 2–5 miles of range per hour of charging time.
- 2) **Level 2** – charges via a 240-V electrical service and uses the same type of plug as a Level 1 charger. Preferred because it can add 10 to 20 miles of range to an EV for every hour of charge time, allowing a completely depleted battery to be fully charged overnight.

### Hawai'i's EVSE Options

| Type of Charger | Voltage Input | Miles/Hour of Charging           |
|-----------------|---------------|----------------------------------|
| Level 1         | 120 V         | 2–5                              |
| Level 2         | 240 V         | 10–20                            |
| DC fast charger | 480 V         | 60–80<br>(full charge <one hour) |

### Leading by Example: Sen. Mike Gabbard

"I bought my Nissan LEAF on April 15, 2011. It was our first new car in over 40 years. It took a bit of arm-twisting to convince my wife, Carol. My sales pitch was, 'Geez, honey, I'm the chair of the energy committee; I have to set a good example.' It worked.

"I charge it up every night at home, which allows me to go about 80 miles between charges. I took advantage of the \$8,500 federal tax credit and \$5,000 state rebate on the purchase of the car and charging station. It's amazing not to have to fill up with gas now that it's well over \$4 a gallon. We're saving about \$250 each month from not having to buy gas. This adds up to \$3,000 a year. Not to mention that we don't need oil changes and other engine work. We've put almost 27,000 miles on our LEAF.

"The free parking and high-occupancy vehicle perks help out tremendously, especially during our legislative session when things are so hectic. I almost forgot ... I smile many times as we drive by our old gas station. I definitely don't miss getting in the long lines, filling up, then gasping when the receipt pops out."

Hawai'i state Sen. Mike Gabbard with his Nissan LEAF. Photo from Mike Gabbard, Senate Office





I really enjoy helping to prove (and improve) EV technology in a real-world setting. This is so important to Hawai‘i’s energy future. We need every Hawai‘i citizen to be personally energy aware and feel responsible for contributing in some way to solving our energy problems. Many of the best contributions are low or no cost, involving changes in behavior and attitudes. Get involved today. You will be proud of what you can do.

— RAY STARLING, Program Director, Hawai‘i Energy



Ray Starling uses his EV for his 30-mile daily commute over Oahu’s Pali Highway. PV panels on his house generate the power needed to charge his EV, saving him money in both electricity and fuel. *Photo from Ray Starling*

3) **Direct current (DC) fast-charging equipment** – uses a 480-volt input that allows for rapid charging and can add 60 to 80 miles of range to an EV battery in 20 minutes. DC fast chargers are ideal for high-traffic areas and public charging stations.<sup>7</sup>

### Integrating EV and Renewable Energy Technologies

As Hawai‘i’s transportation transformation shifts into overdrive, EV owners are reaping the benefits—cruising through traffic in the high-occupancy vehicle lane, parking free of charge at state-owned locations, and enjoying the significant cost savings that high-efficiency vehicles and off-peak charging provide.

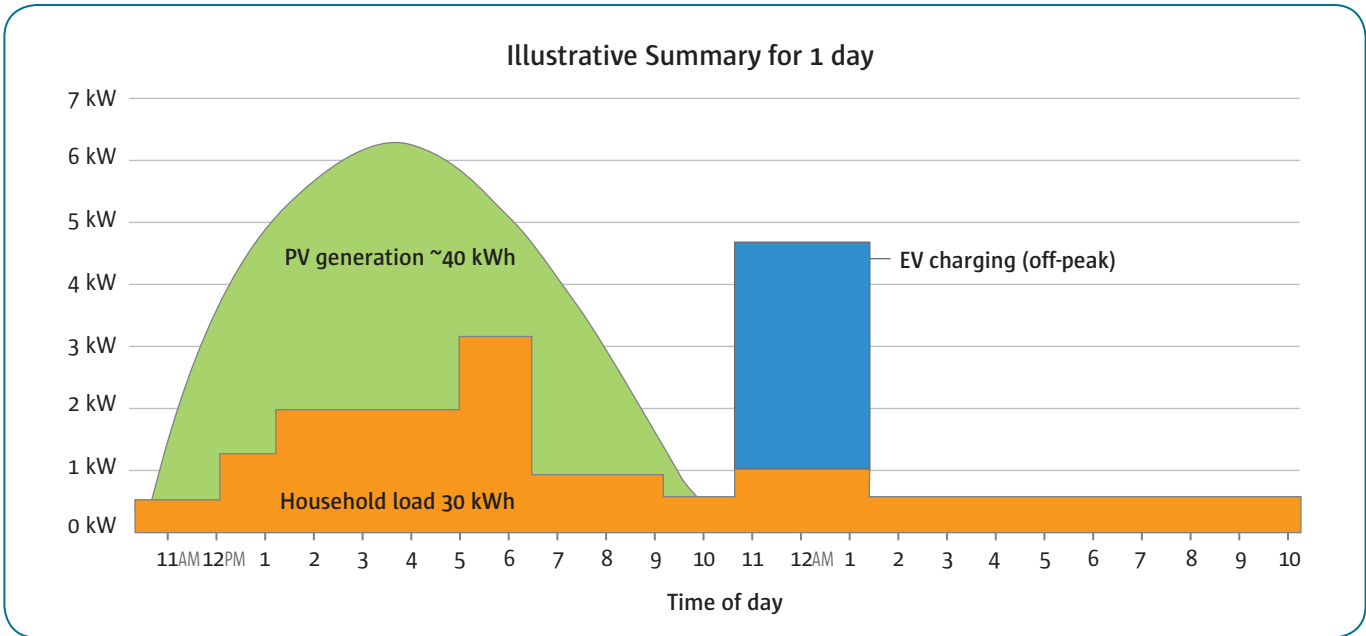
For those who have gone the extra mile by installing rooftop solar photovoltaic (PV) systems on their homes, there is another plus: the electricity generated by the solar panels to power their homes offsets the cost of the electricity they draw from the grid to charge their vehicles, increasing their savings even more. And as a growing number of shopping centers, hotels, and other businesses install carports equipped with rooftop solar PV systems, EV drivers’ opportunities to power their cars with clean, renewable energy become greater.

### EV + PV = Big Savings for Hawai‘i Resident

In April 2011, Hawai‘i resident Ray Starling purchased an EV. Since he had already had a solar water heater for 10 years and 6.5 kilowatts (kW) of rooftop PV for 2 years, adding an EV to the mix was an easy choice. Two years later, Starling has driven approximately 16,100 miles and used approximately 4,773 kilowatt-hours (kWh) of his own solar power to charge his EV, yielding about 3.4 miles per kWh (including some losses in the battery). If he had been purchasing power from the local utility, he would have spent approximately \$0.32 per kWh (at the regular residential rate) or approximately \$1,595 to drive the 16,100 miles (\$0.10/mile). If he had been driving a gasoline-fueled vehicle at the average 22 miles per gallon, the same 16,100 miles would have cost him \$3,168 (at \$4.30/gallon, or \$0.20/mile). However, because he generated his own kilowatt-hours, he actually paid nothing to the electric utility and incurred no gas costs for his transportation. (See the graph on page 11 for an illustrative example of how the energy generated by a residential rooftop solar PV panel array “pays” for an EV to charge.)

For early technology adopters like Ray Starling and others, there are broader economic and environmental advantages as well. First, because EVs are more efficient than conventional vehicles and are powered by electricity, EV drivers are helping to reduce the amount of fossil fuel consumed in Hawai‘i’s transportation sector. And because they charge their vehicle batteries from the grid instead of filling up

<sup>7</sup> *Plug-In Electric Vehicle Handbook for Public Charging Station Hosts*. DOE/GO-102012-3275. DOE Clean Cities Program, 2012. <http://www.afdc.energy.gov/pdfs/51227.pdf>.



As shown in this graph, all the household’s electricity needs, including EV charging, can be provided by a properly sized rooftop solar array. The EV charging, done during off-peak hours for even more savings, is enough for approximately 24 miles of driving—a typical daily commute in Hawai‘i.

*Illustration by NREL*

with a tank of gas, they are also helping to diversify the source of transportation energy, which further contributes to Hawai‘i’s clean transportation goal.

Furthermore, as the number of solar PV systems and wind farms installed throughout the islands continues to rise and renewable energy represents a greater portion of Hawai‘i’s overall energy generation, more of the electricity consumed by EVs will come from renewable sources, moving Hawai‘i closer to its 70% goal.

### The Smart Grid: A Holistic Solution

As Hawai‘i’s energy generation mix shifts to more renewable sources, and as the number of EVs drawing electricity from the grid reaches a critical mass, new challenges may come into play. Smart grid technology and evolving EV charging systems could help usher in a new era where EVs and building load management are closely coupled to facilitate higher levels of renewables on the grid. Hawai‘i is poised to become

an early adopter and international test bed for this technology.

To mitigate the impacts of more intermittent energy on the grid and more EVs on the road, utilities must find innovative ways to balance the energy load and maintain grid reliability. For example, when a cloud passes over the sun in west Oahu or the wind suddenly drops off on the North Shore, the utility has to be able to continue providing reliable power to meet customer demands. Likewise, if tens of thousands of EV owners around the islands plug in their cars to charge while they sleep, the utilities have to be able to accommodate a potential spike in demand to maintain reliable service across the distribution system.

Such scenarios call for Hawai‘i’s utilities to become highly flexible, resilient, and responsive to high levels of intermittent generation and new load profiles in ways the small island grids were not originally designed for. To achieve this, Hawai‘i’s energy distribution systems must implement intelligent systems, such as synching with wireless

communications to enable real-time two-way communication between the utilities and their customers.

A smart grid system can synch existing utility generation, transmission, and distribution lines with wireless communications systems to transmit data about energy generation and demand in real time to efficiently manage the distribution of power throughout the grid. This functionality will enable the grid to operate reliably and safely as renewable sources provide a greater portion of Hawai‘i’s energy generation. Automotive industry leaders and research organizations, such as DOE’s NREL, are developing and testing prototypes of EVs (and accompanying charging equipment) that could enable vehicle-to-grid (V2G) power exchange. By providing power to utility and local loads, these V2G-capable vehicles could support voltage and frequency regulation and enhance electrical demand management by absorbing excess electricity produced by renewable energy sources when the grid is operated at low load conditions.

# Electric Vehicles and Hawai'i's Evolving Smart Grid

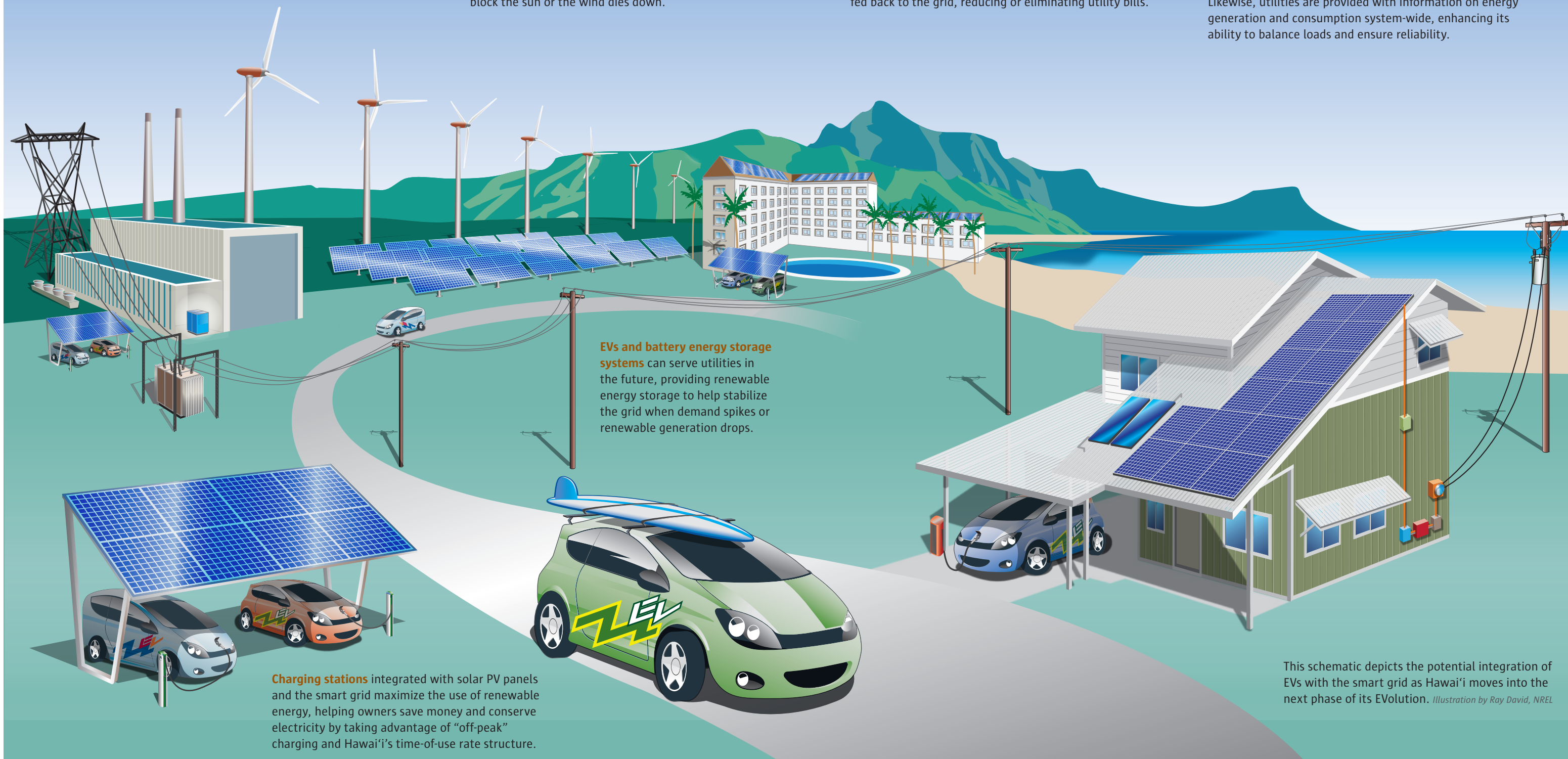
Improving reliability, integrating renewable electricity with clean transportation, and helping consumers save

**Information and control systems** enable utilities to monitor and manage electricity demand and delivery, preventing outages caused by sudden drops in energy production from intermittent sources such as wind and solar and/or spikes in demand.

**Community-scale wind and solar generation combined with smart grid technologies** allows utilities to maintain a steady flow of electricity throughout the distribution system when clouds block the sun or the wind dies down.

**Solar PV arrays** installed on carports and rooftops can be used to charge EVs, run air-conditioners, and more. When these systems produce more energy than is consumed on-site, net-metering allows the excess to be fed back to the grid, reducing or eliminating utility bills.

**Smart meters** enable the wireless exchange of information between homes and utilities, giving homeowners real-time data on their energy use, which allows them to change behaviors to reduce consumption. Likewise, utilities are provided with information on energy generation and consumption system-wide, enhancing its ability to balance loads and ensure reliability.



**EVs and battery energy storage systems** can serve utilities in the future, providing renewable energy storage to help stabilize the grid when demand spikes or renewable generation drops.

**Charging stations** integrated with solar PV panels and the smart grid maximize the use of renewable energy, helping owners save money and conserve electricity by taking advantage of "off-peak" charging and Hawai'i's time-of-use rate structure.

This schematic depicts the potential integration of EVs with the smart grid as Hawai'i moves into the next phase of its EVolution. *Illustration by Ray David, NREL*



The County of Hawai'i's new EV fleet includes five Chevy Volts—these “extended range” EVs can accommodate longer driving distances on the Big Island. The county offset the \$47,000 price tag for each car with a \$4,500 rebate per car through the state's EV Ready Program. *Photo from Bobby Command, County of Hawai'i Mayor's Office*

The marriage of vehicle technology innovation and “smart” electricity distribution infrastructure on a community scale is still in the conceptual phase. In theory, the disparate elements of the smart grid will integrate seamlessly to increase consumers' ability to control their energy use and costs while enhancing utilities' ability to mitigate the impact of more intermittent renewable energy generation on the grid. In practice, however, their integration is exceedingly complex.

But the systems integration challenge that is occupying scientists and engineers around the world represents another opportunity for Hawai'i.

### U.S. Army Demonstration

The U.S. Army is already demonstrating integrated power systems developed by its Detroit-based Tank Automotive Research, Development and Engineering Center (TARDEC) as part of the Smart-Charging Micro Grid (SCMG) pilot at the U.S. Army Garrison-Hawai'i.

Comprising a 25-kW PV system, a battery with 200 kWh of storage capacity, and four EVs, the SCMG not only powers the EVs but is also capable of providing on-demand backup power to support Garrison headquarters and two other buildings for up to 72 hours. TARDEC recently developed a second microgrid system at the nearby Schofield Barracks to demonstrate efficient management of power, integration of renewable energy, energy storage, smart charging of EVs, and the ability to take these capabilities to forward operating bases.

### Maui Smart Grid Project

On Maui, where renewable energy already provides 15% of the island's energy, Hawai'i and Japan have launched the Japan-U.S. Grid Partnership. The project is part of the Hawai'i-Okinawa Partnership on Clean and Efficient Energy Development and Deployment, which was signed by DOE; the Ministry of Economy, Trade and Industry of Japan; the state of

Hawai'i; and the Prefecture of Okinawa in June 2010. The Japan-based New Energy and Industrial Technology Development Organization (NEDO) is spearheading the project with a \$37 million investment involving Hitachi Ltd., Mizuho Corporate Bank, Cyber Defense Institute, Hewlett-Packard Japan, HECO, HNEI, and DOE's national labs. The project is aimed at optimizing the integration of renewable energy resources onto the grid while at the same time preparing the electrical system for increased use of EVs. Led by Hitachi, the project will test advanced smart grid and smart meter technologies in 40 households in Kihei, Maui, along with an advanced EV charging management system and a network of publicly available DC fast chargers on Maui. The system, which will connect MECO system controls with charging stations island-wide, is designed to enable MECO to manage EV charging, and balance generation with load by making better use of the wind and solar resources that are already providing energy to the grid.

### Partnering to Bring About Change

Hawai'i's collaborative can-do spirit has played a vital role in the successful debut of alternative fuel vehicles, including EVs, in Hawai'i. Numerous partnerships among local organizations, state and federal government agencies, and the private sector have contributed to propelling the state's transportation sector forward on its path toward a clean energy future, including:

- **DBEDT's State Energy Office,** which has been at the forefront in facilitating a climate conducive to expanding the Hawai'i EV market by developing EV-friendly policies, attracting national and international

EV industry investment, and helping coordinate business interests with state and local government organizations. DBEDT developed and managed the highly successful EV Ready Program and stepped in to help lead the Honolulu Clean Cities Program into the EV era.

- **DOE**, which has provided leadership, federal funding for the EV Ready Program, hydrogen demonstrations and analysis, smart grid projects, support for the Honolulu Clean Cities Program, and resources through its national laboratories. NREL has been a co-chair of the Transportation Working Group and provided technical analysis and expertise in EV and renewable grid integration, transportation policy analysis, and strategic planning.
- **U.S. Department of Defense (DOD)**, which is a critical partner in Hawai'i including its role in the use and development of transportation fuels and advanced transportation technologies such as EVs and hydrogen fuel cell vehicles. The U.S. Pacific Command actively supports the goals of HCEI and helps to coordinate DOD energy activities among the services. DOD research labs, including the Air Force Research Lab, the Office of Naval Research, and TARDEC, each have advanced vehicles and fuels technology demonstrations in Hawai'i and military bases host demonstrations and are incorporating clean vehicle technologies into their fleets.
- **The Hawaii Center for Advanced Transportation Technologies (HCATT)** is an attached agency of DBEDT and has been a driving force for EVs and EV charging infrastructure since the early 1990s, when it was originally established as the Hawaii Electric

Vehicle Demonstration Project. More recently HCATT has been working with the Air Force Research Laboratory at Pearl-Hickam Joint Base demonstrating hydrogen production from renewables and hydrogen vehicle fueling.

- **Hawai'i Automotive Dealers Association (HADA)** (see feature on page 19).
- **Nissan North America, Inc.**, which has a Definitive Agreement with the state of Hawai'i to promote the use of EVs and charging infrastructure on the islands. In early 2011, Nissan North America announced that Hawai'i would be one of its initial launch markets for the all-electric Nissan LEAF in the United States.
- **HECO** (see feature on page 18).
- **HNEI**, which is a research organization unit of the University of Hawai'i that has been a champion of research and demonstration of EV, hydrogen, and fuel cell technologies in Hawai'i for many years. Among other leading research activities, HNEI also has been very involved with renewable grid integration efforts and smart grid technology demonstrations.
- **Mitsubishi Motors North America Inc.**, which in June 2011 entered into a Memorandum of Understanding (MOU) with the state of Hawai'i to increase awareness and adoption of EVs and to assist in the rapid deployment of EV charging infrastructure. In December 2011 Mitsubishi Motors North America made the first customer retail delivery of the electric-powered 2012 Mitsubishi iCar in Honolulu. Hawai'i was the first state to receive the North American version of the company's EV.



Hawai'i's government is embracing renewable energy technologies and leading by example, as shown in this photo of the West Hawai'i Civic Center (background), with its 250-kW solar PV array (foreground). Photo from Drew Bradley, REC Solar

### West Hawai'i Civic Center

On Hawai'i Island, Kailua-Kona is now home to the 85,000-square-foot West Hawai'i Civic Center (WHCC) complex, which includes 22 county agencies and one state agency, a pavilion and community center available to groups and local residents, and a 250-vehicle parking structure powered by a 250-kW solar PV array, which earned the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Silver designation. On the road, WHCC has a fleet of 42 vehicles that are driven every weekday for a variety of reasons.

NREL analyzed WHCC's plans and likelihood for long-term sustainable development and revealed that with the right additions and adjustments, the county has the potential to become a leader in solar-to-EV adoption. NREL found that for each EV purchased to replace a gasoline vehicle, the county would save more than \$10,000 over six years.<sup>8</sup> Also, with its solar-powered parking facility already in place, WHCC has a significant opportunity to use the excess power generated by the PV array to allow for daytime EV charging.

"We expect to save 50% on our electric bills with this combination over the year," said Will Rolston, Energy Coordinator for the County of Hawai'i. "We also expect to save 50%-75% on transportation fuels for our five PHEVs (depending on roundtrip distance, driving style, and topography). This combination of energy for electricity and transportation at a LEED-Silver facility is unique for the state of Hawai'i."

<sup>8</sup> Kuss, M. C.; Markel, T. J.; Simpson, M. B.; Helwig, M. S.; Jun, M.; Kelly, K. J. *Evaluation of West Hawai'i Civic Center's Transportation and Energy Use*. NREL/TP-5400-53173. Golden, CO: National Renewable Energy Laboratory, 2013.

*Continued on page 18*

# Timeline of Hawai'i's EVolution

1993

The Hawai'i Electric Vehicle Demonstration Project was established, now known as HCATT. The purpose of HCATT is to bridge the gap between private industry and the federal government to accelerate the development and benefits of EV technologies and to reduce dependence on imported petroleum.

1997

Act 290 was passed to establish EV license plates, provide permit-free parking for EVs at state and county facilities (including parking meters), and allow EVs with a single occupant access to Hawai'i high-occupancy-vehicle lanes.

2004

The Oahu transit system, TheBus, added 10 HEV buses to its fleet.

## Phase 1

2008

An energy agreement was established between the state of Hawai'i and HECO to encourage the deployment and adoption of EVs.

**HCEI was launched by the state of Hawai'i and DOE to pave the way for energy independence in Hawai'i, including ground transportation.**

An MOU was signed between Better Place and HECO to develop an EV infrastructure and charging and operating system in Hawai'i.

Hawai'i's EVolution can be viewed in three early development phases. In phase 1 (2008–2010), the state laid the groundwork for a major shift in the marketplace by introducing financial incentives and EV-friendly policies that would encourage consumers to purchase EVs.

In phase 2 (2011), automakers Nissan, Mitsubishi, and General Motors (GM) entered Hawai'i market to fill the demand for EVs that had been created in phase 1.

In phase 3 (2012), EVSE manufacturers joined in, installing the public charging infrastructure required to service the nearly 1,100 EVs that were traveling on Hawai'i's roads by the end of 2012.

In the next phase, the vision is to prime Hawai'i for EV integration with smart grid technologies to enable even higher levels of renewable energy on its grids.

|  |  | Phase 2  | Phase 3  |
|--|--|--|--|
| <p><b>2009</b></p> <p>An amendment to Hawai'i's renewable energy law, Act 155, was passed to require Hawai'i's electric utility companies to provide at least 25% renewable energy by 2020 and 40% renewable energy by 2030.</p> <p>Act 156 was passed to require that any parking lot with at least 100 or more publicly available parking stalls set aside 1% of parking spaces for EVs and equip at least one of those spaces with charging capability. The law also encouraged the development of non-fossil-fuel transportation as a state policy goal and required state and county agencies to purchase EVs and other alternative-fuel vehicles.</p> <p><b>The Transportation Energy Diversification EV Ready Program received \$4.5 million in Recovery Act funding from DOE's State Energy Program to encourage the adoption of EVs and EV charging equipment in Hawai'i.</b></p> | <p><b>2010</b></p> <p>Act 186 was passed to prevent homeowners associations from prohibiting solar and energy-efficient devices, including EV chargers.</p> <p><b>The Oahu transit system added another 20 new HEV buses to its fleet, bringing the total to 80.</b></p> <p>HECO time-of-use pilot program was approved by the Public Utilities Commission.</p> <p>Hawai'i Auto Show featured EV technology heavily.</p> | <p><b>2011</b></p> <p><b>Japan's NEDO announced the Maui Smart Grid Project.</b></p> <p>Nissan delivered Hawai'i's first 100% electric Nissan LEAF.</p> <p>Fifty Mitsubishi iMiEVs hit the streets of Hawai'i.</p> <p>The Chevy VOLT became available in Hawai'i.</p> <p>Enterprise Rent-A-Car added 20 EVs to its fleet and installed 10 EV chargers.</p> <p>Ford added Honolulu to its "top 25" list of EV-friendly U.S. cities.</p> | <p><b>2012</b></p> <p>Hawai'i established an EV charging network and installed more than 200 chargers across the islands.</p> <p>Aloha Petroleum installed the first DC fast chargers at Hawai'i gas stations.</p> <p>Number of EVs on the road exceeded 1,100.</p> <p><b>EV Ready Program was successfully completed, awarding 453 rebates for EVs and 274 rebates for public and private charging stations.</b></p> <p>Ford Focus hit the Hawaiian market.</p> |





From sun to run: PV solar panels power an EV at a HECO carport charging station. *Photo from HECO*

## Hawaiian Electric Company

HECO and its subsidiaries, MECO and HELCO, serve more than 1 million residents on Oahu, Moloka'i, Lana'i, Maui, and the Big Island. A key player in Hawai'i's goal of 70% clean energy by 2030, HECO has encouraged the adoption of EVs by:

- Demonstration testing a discount time-of-use electric rate for EV owners who charge their vehicles at home during off-peak hours
- Requesting regulatory approval of a second EV discount rate to encourage commercial customers and allow the utility to provide DC fast chargers in public places
- Educating the public about the value of electric transportation, including co-sponsoring Honolulu's annual auto show for three straight years
- Cooperating with Electric Power Research Institute on a "carport of the future" study about charging EVs from rooftop solar PV panels
- Encouraging customers with EVs and rooftop solar PV to "cruise on sunshine" by combining discount time-of-use rates and net metering to enjoy even greater savings
- Assisting in third-party installations of public EV charging systems, including DC fast chargers, at strategic locations throughout the community
- Continuing to grow the company's branded EV fleet along with increasing HEVs.

"An Edison Electric Institute study found almost two-thirds of utility customers want us 'to take a leadership role in (the) shift toward electric transportation.' Those customers in Hawai'i and across the country will also be buying new cars this year and years to come. We should listen to them," said Robbie Alm, HECO executive vice president. "The EV offers Hawai'i the opportunity to reduce our dependence on imported oil by greening transportation and electric power at the same time. It really is a double win for Hawai'i."

- **Hawai'i Gas and General Motors**, which launched the Hawai'i Hydrogen Initiative (H2I) in partnership with the state, DOE, U.S. Pacific Command, HNEI, and a suite of public and private partners. The goal of H2I is to make hydrogen-powered vehicles, as well as fueling infrastructure, a reality by making hydrogen stations readily available to all Oahu residents by providing 20–25 fueling stations by 2015.

## Moving Forward, Maintaining Momentum

Policies, funding, and incentives have been set in motion in Hawai'i. A variety of EV makes and models have been introduced to the Hawai'i market and are being purchased and driven with success. Charging stations are being installed throughout the state. Corporations, business owners, nonprofit organizations, policymakers, and government agencies are all working together toward a common goal, collaborating on a variety of projects and initiatives, including smart grid pilots aimed at bringing a variety of technology innovations together to optimize all the systems involved in Hawai'i's energy transformation. For Hawai'i, it's no longer a matter of needing the change to happen, but making the most of an opportunity it has already seized.

To keep the positive momentum going, HCEI recommended that a process be in place from 2012 on to carefully measure accomplishments and ensure that goals are being met. By the end of 2015, more policies that promote the transition to clean transportation will be in place in Hawai'i and more EVs will be on the road along with more convenient charging locations. Wind, solar, biomass, and geothermal energy will provide more of Hawai'i's energy. And by 2020, the state of Hawai'i and its partners on the path to a clean energy future will have a more thorough understanding of EVs, EV infrastructure, their integration with renewable energy and smart grid technologies, and the challenges and benefits of their large-scale deployment.

## Manawa Kupono

Sometimes conditions align to create the perfect opportunity for change, which seems to be the case in Hawai'i today. Previous attempts to implement EVs into the state may have run into obstacles or stalled completely, but today's innovative technologies, paired with numerous opportunities to meet the state's growing energy demands, have set the stage for clean energy and the EV. Dave Rolf of HADA agrees: "The Hawaiian words for opportunity are *manawa kupono*, meaning there is a season, a right time. Those of us in Hawai'i believe it is *manawa kupono*. We see much being invested in the islands to transition to renewable fuels. The electric car provides a way for everyone to come to a clearer understanding of the value of a transition to clean energy."



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### Hawai'i Automotive Dealers Association

Local auto dealers have played a key role in the success of Hawai'i's EV market—touting the benefits of EVs to consumers, selling and servicing the vehicles, and training technicians. HADA has been an important partner in supporting the clean transportation goals of HCEI—educating the public on fuel efficiency, providing information and feedback from the auto dealers, investing in the installation of EV infrastructure and EV readiness training, and working with auto manufacturers to promote the Hawai'i market. HADA's efforts have helped propel Hawai'i to the top of the ranks for EV adoption worldwide. Currently, five EV models are available in the state, including the Nissan LEAF, Chevrolet Volt, Mitsubishi iMiEV, Ford Focus, and Toyota Prius, with many more models to come.

HADA strives to make buying a new car an easy, trouble-free process. With the new technologies available and the move toward a clean energy future, HADA is also focused on educating the public on the benefits of EVs as well as on why Hawai'i has the perfect opportunity to lead the way. Dave Rolf, executive director of HADA, stated, "Hawai'i is to the electric car what Napa is to the grape—perfect conditions, ideal temperatures for battery operation, short commutes, a willing consumer base for the product, and public policy decisions that are encouraging adoption (free parking for EVs in Honolulu, use of high-occupancy vehicle lanes, cash rebates for purchase of EVs, lower charging rates at off-peak hours, and EV charging stations mandated in large public parking lots)."

Four months before the January 2011 launch of Nissan's LEAF in Hawai'i, 300 vehicles had already been pre-ordered—the highest per-capita embrace of the LEAF of any of the seven U.S. rollout markets. Nissan's overwhelming success in Hawai'i attracted other manufacturers, including Mitsubishi, GM, and Ford.

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**For more information on efforts to transform Hawai'i's transportation sector, visit:**

- Hawai'i Clean Energy Initiative:  
[www.hawaiiicleanenergyinitiative.org/transportation](http://www.hawaiiicleanenergyinitiative.org/transportation)
- EV Ready Program:  
<http://energy.hawaii.gov/programs/transportation-on-the-move/ev-ready-program>

*Cover photo by Ken Kelly, NREL 24514. Page 2, from top: Ken Kelly, NREL 24512; iStock 1359888; Ken Kelly, NREL 24520. Page 3, from top: from Margaret Larson, DBEDT; iStock 9468980; Ken Kelly, NREL 24515. Page 19, from left: from Maui Electric Vehicle Alliance; from Margaret Larson, DBEDT; from Jamey Steiner, Volta Industries. Back photos from iStock, from left: 7093707, 1959032, 10196394, 92289, 3961713*

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