California Solar Initiative

RD&D: Research, Development, Demonstration and Deployment Program

GO solar CALIFORNIA

Final Project Report:

# Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition

Grantee:

Clean Power Research

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www.CalSolarResearch.ca.gov

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# Preface

The goal of the California Solar Initiative (CSI) Research, Development, Demonstration, and Deployment (RD&D) Program is to foster a sustainable and self-supporting customer-sited solar market. To achieve this, the California Legislature authorized the California Public Utilities Commission (CPUC) to allocate **$50 million** of the CSI budget to an RD&D program. Strategically, the RD&D program seeks to leverage cost-sharing funds from other state, federal and private research entities, and targets activities across these four stages:

- Grid integration, storage, and metering: 50-65%
- Production technologies: 10-25%
- Business development and deployment: 10-20%
- Integration of energy efficiency, demand response, and storage with photovoltaics (PV)

There are seven key principles that guide the CSI RD&D Program:

1. **Improve the economics of solar technologies** by reducing technology costs and increasing system performance;
2. **Focus on issues that directly benefit California**, and that may not be funded by others;
3. **Fill knowledge gaps** to enable successful, wide-scale deployment of solar distributed generation technologies;
4. **Overcome significant barriers** to technology adoption;
5. **Take advantage of California's wealth of data** from past, current, and future installations to fulfill the above;
6. **Provide bridge funding** to help promising solar technologies transition from a pre-commercial state to full commercial viability; and
7. **Support efforts to address the integration of distributed solar power into the grid** in order to maximize its value to California ratepayers.

For more information about the CSI RD&D Program, please visit the program web site at www.calsolarresearch.ca.gov.

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## Executive Summary

Under the California Solar Initiative (CSI) Research Development, Demonstration and Deployment (RD&D) Program grant, established by the CPUC and managed by Itron, Clean Power Research developed PV and PEV modules within a new online tool called WattPlan®. This tool now helps IOU customers in California understand the benefits of combining an electric vehicle purchase with solar PV. The tool's personalized analysis, tailors results for each user and includes analysis with regard to the economic, energy and environmental savings of investing in an electric vehicle plus solar PV. The tool can be found at https://csi.wattplan.com.

While "eco-consciousness" and a degree of affluence in the customer bases for PV and PEVs have played a significant role in adoption thus far, there is an opportunity to broaden both markets. One way to reach a wider audience is to demonstrate how PV and PEVs complement each other and often provide greater savings when combined. This requires making both technologies approachable and understandable, which is best done by personalizing each analysis and emphasizing the economics.

WattPlan allows utility customers to easily explore:

- Bill savings potential with technologies such as PV and PEV.
- Optimal electric rate plan and charge time.
- Available tax credits and rebates.
- Optimal PV system size.
- Relevant market statistics, including what their neighbors and others in their communities are doing with regard to PV and PEV technology adoption.

As part of CSI RD&D funding, this tool will be available to all California IOU customers for one year, through September 30, 2016.

## Introduction

Clean Power Research (CPR) proposed to develop further California's self-sustaining solar market through an online consumer information platform that ties into the rapid growth of electric vehicles in California.

The U.S. plug-in electric vehicle (PEV) market has grown substantially, particularly in California, where according to Clean Vehicle Rebate Project statistics, 2014 PEV adoption increased by an order of magnitude over the previous three years.[1] California is the nation's largest PEV market with some 100,000 vehicles and new sales adding about 3,500 additional cars in the state each month.

The strong correlation between PEV and PV owners has been well documented. A 2013 survey of 1,419 PEV owners performed on behalf of the California Center for Sustainable Energy (CSE)

[1] https://cleanvehiclerebate.org/eng/rebate-statistics

and the California EPA Air Resources Board (ARB) found that 39% of PEV owners currently have solar, and another 17% are considering going solar within the coming year.[2] While PV and PEV adoption is driven in large part today by a sense of "eco-consciousness" and to some degree by a level of affluence in the customer bases for both technologies, there is a great opportunity to broaden both markets by demonstrating this complementarity to a wider audience. To do this, it is critical to make both technologies approachable and understandable while personalizing analyses and emphasizing the economics.

The proposed platform includes easy-to-use, but powerful web-based tools that allow a range of Californians to receive personalized analyses with regard to PV and PEVs.

## Project Objectives/Project Approach

The purpose of this project was to modify and enhance Clean Power Research's existing solar sustained vehicle (SSV) web service and develop an intuitive user interface around this enhanced SSV web service.

The modifications and enhancements to the SSV web service were intended to make it more meaningful to the everyday user. Updates included 1) the integration of personalized driving and charging habits, 2) the separation of technology financing methods, for instance, modeling 25-year PV lease combined with a 5-year PEV loan and analyzing the combined cash flow, and 3) the integration of smart meter (e.g., Green Button) data.

The planned responsive user interface would add value and meaning to the detailed analytics and collated market statistics helping to drive action by end-users. This new interface would also allow a user to obtain results quickly and with minimal input.

[2] http://energycenter.org/sites/default/files/docs/nav/transportation/cvrp/survey-results/California_Plug-in_Electric_Vehicle_Driver_Survey_Results-May_2013.pdf

## Project Outcomes/Conclusions

Throughout this project several versions of the SSV web service were developed and released through Clean Power Research's Agile software development process. The enhanced SSV web service builds on the legacy application's code. The SSV web service was designed to include all inputs and outputs necessary for interaction with the user interface, the second key outcome resulting from the project. The modular web services developed include:

- **PEV modeling web service** with user configurable variables impacting PEV charge/discharge behavior and PV system sizing.
- **Financing web service** designed to effectively model separate financing methods per technology and then display combined cash flow results.
- **Interval-level load data,** including Green Button format.

The user interface, built around the SSV web service, provides a step-wise user experience, while leveraging the quick and accurate results from the service. This interactive interface relies on a map to present PV and PEV market statistics in a compelling intuitive fashion. Responsive design was a focus throughout the project, ensuring the user interface is optimized for tablets and adaptable to smaller devices such as smartphones. The platform was officially launched on September 23, 2015.

## Case Study and Methodology Development

To develop the exact methodology behind the PEV modeling web service and as part of developing a broader Zero Net Energy including transportation (ZNET) concept, Tom Hoff focused specifically on compiling case study results with respect to PV+EV.

Figure 1 below shows actual costs associated with a typical California household's driving behavior. Results show that when the EV was leased in H2 2013, gasoline and maintenance costs dropped drastically. This analysis includes the commissioning on a PV system and rate plan switching.

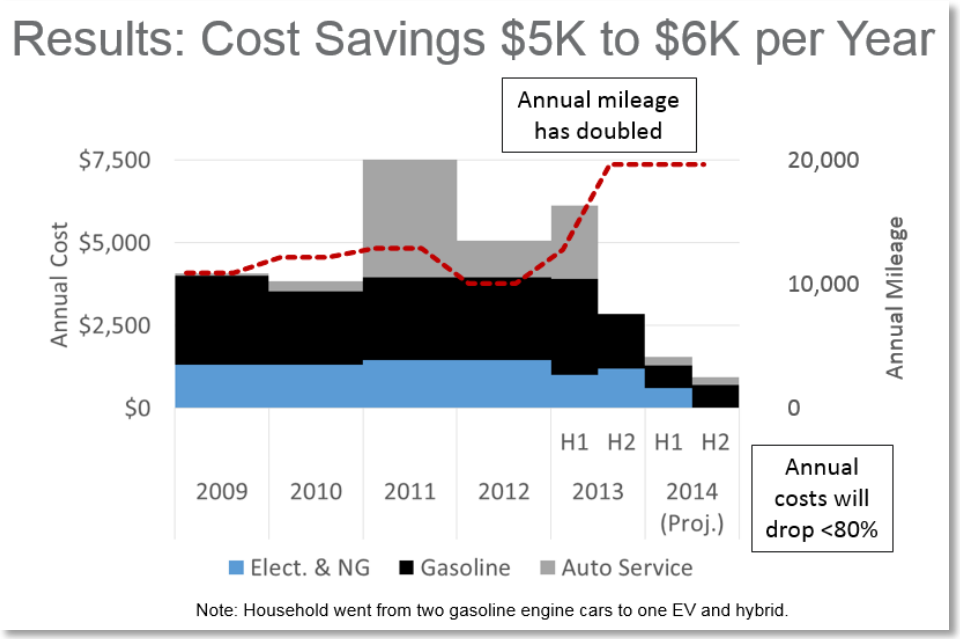



*Figure 1 – Early Case Study Results*

Figure 2 below shows the financial savings potential of adopting PV, an EV, other energy technologies, and additional PV capacity to meet the added electrical load due to intelligent fuel switching technologies.

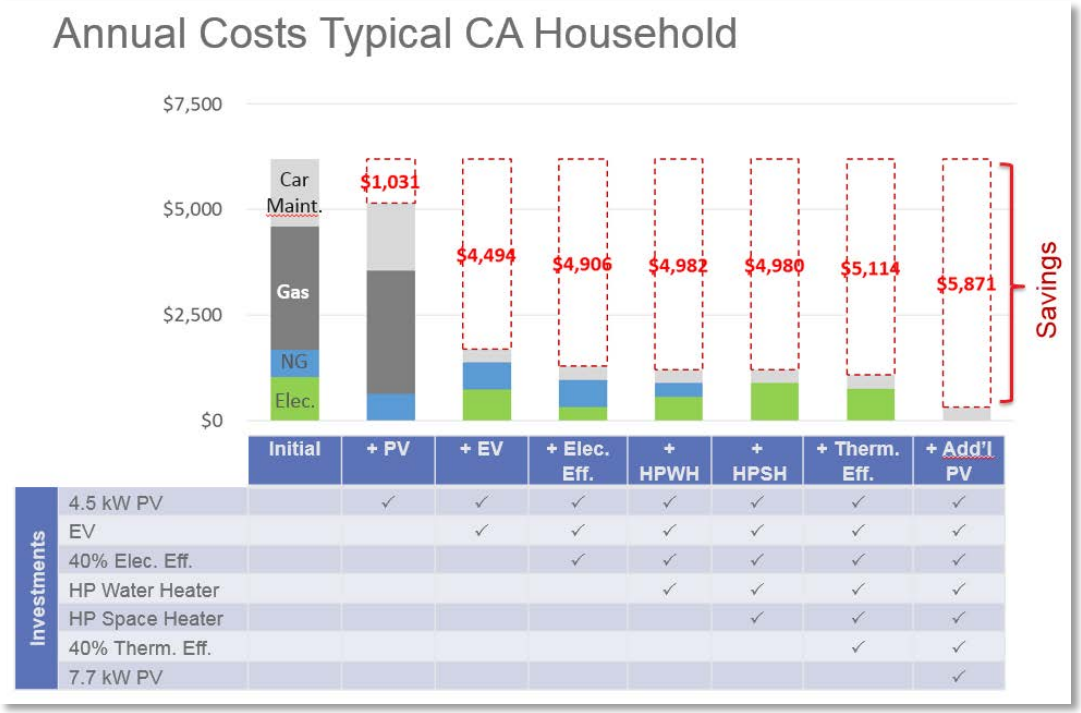



*Figure 2 – ZNET Concept and Savings Potential*

## SSV Web Service Enhancements

The concepts and methodologies developed as part of the case study were integrated into the PV+EV decision-making software platform. Some specific enhancements account for hardware specifications and unique driving habits, including the number of miles driven per weekday/weekend and type of travel miles (i.e. city verses highway). The inclusion of these variables allow the model to account for the way these factors impact EV charge/discharge behavior thus capturing their impact on PV system sizing decisions. Along these lines, workplace charging, including the cost to charge was also added.

To develop the modular financing web service CPR developed the EV financing module and then combined it with the existing legacy solar financing module. This achieved the goal of effectively modeling separate financing methods by technology (i.e. PV and EV), then presenting the combined cash flow result.

Support for interval-level data was enhanced so that interval data in hourly and sub-hourly, energy consumption data file formats can now be accepted. This enables Green Button data or smart meter data to be incorporated into the modular bill analysis web service, which calculates before and after electric bill results. Fuel savings calculations were also completed to compare the incremental electric bill due to EV charging with gasoline costs.

Other notable enhancements include a basic database of EV incentives, a combined (PV+EV) environmental impact analysis, a new more accurate API based on the SolarAnywhere TGY®

10km irradiance dataset, and a holistic lifetime cost table and chart showing all of the costs associated with the solar-powered EV compared to a conventional vehicle.

The SSV web service documentation, Appendix A "Product Manual: WattPlan Vehicles," was developed and describes the methodology used for key calculations and describes defaults and assumptions.

## Development of an Intuitive User Interface

The interface's development took a phased approach; first incorporating EV-specific functionality followed by integration of the solar-specific attributes of the tool. Screenshots of the user interface are shown below.

The first, Figure 3 shows the landing page for the California Solar Initiative's PV and PEV WattPlan calculator. This page greets users and provides an overview of what the tool provides.

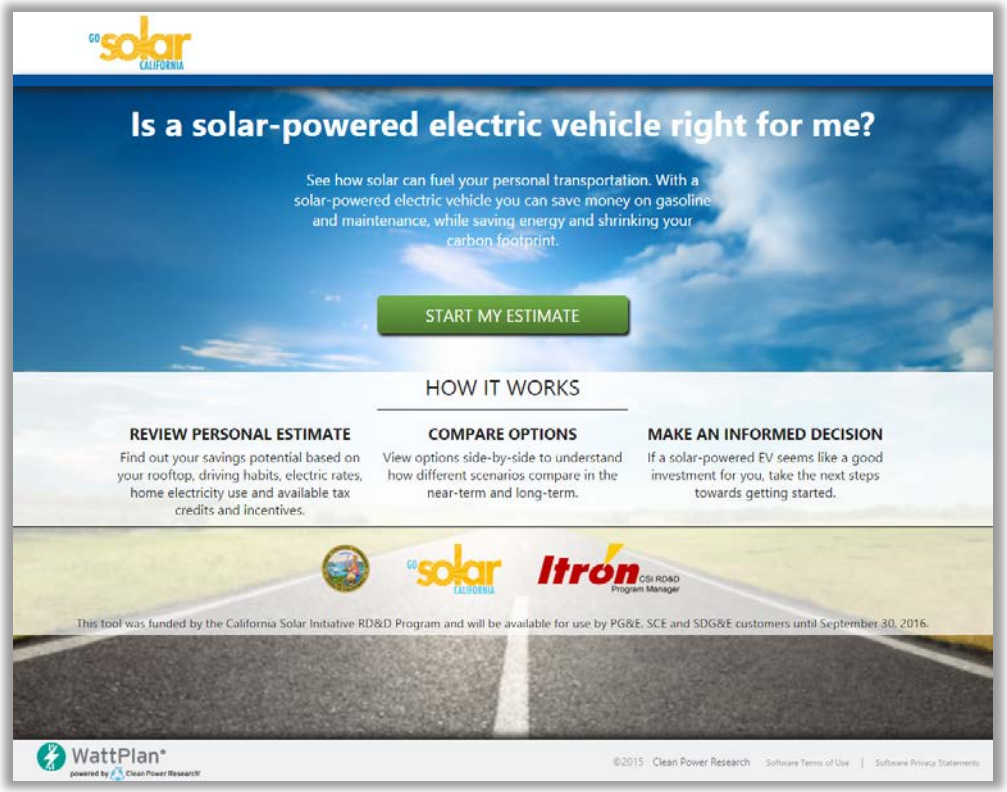



*Figure 3 – Landing page for California Solar Initiative WattPlan PV and PEV calculator tool.*

Next, after clicking Start My Estimate, the user advances to an input Wizard (pictured in Figure 4 and Figure 5 below). The Wizard personalizes the user experience from the start by prompting users to choose which vehicles to compare, input average daily miles driven and the location of their home. For electric data, the user can either select an average electric bill or upload their own interval level Green Button data.

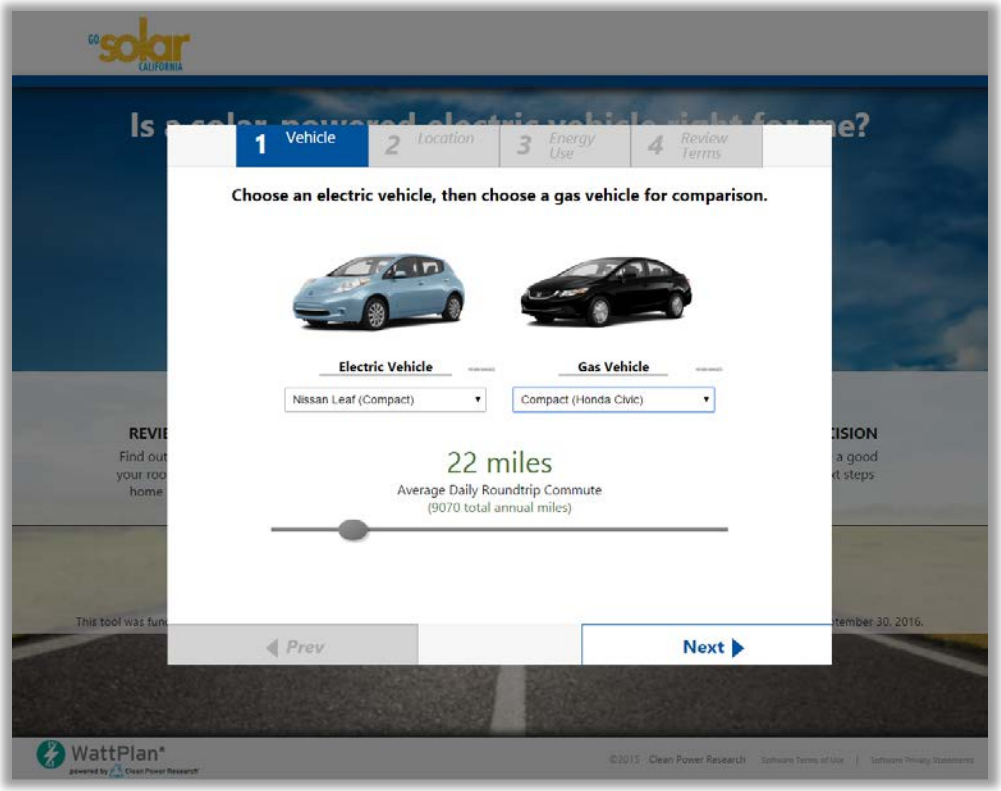



*Figure 4 – Step 1 of the Input Wizard or the Vehicle Selection to Compare tab.*

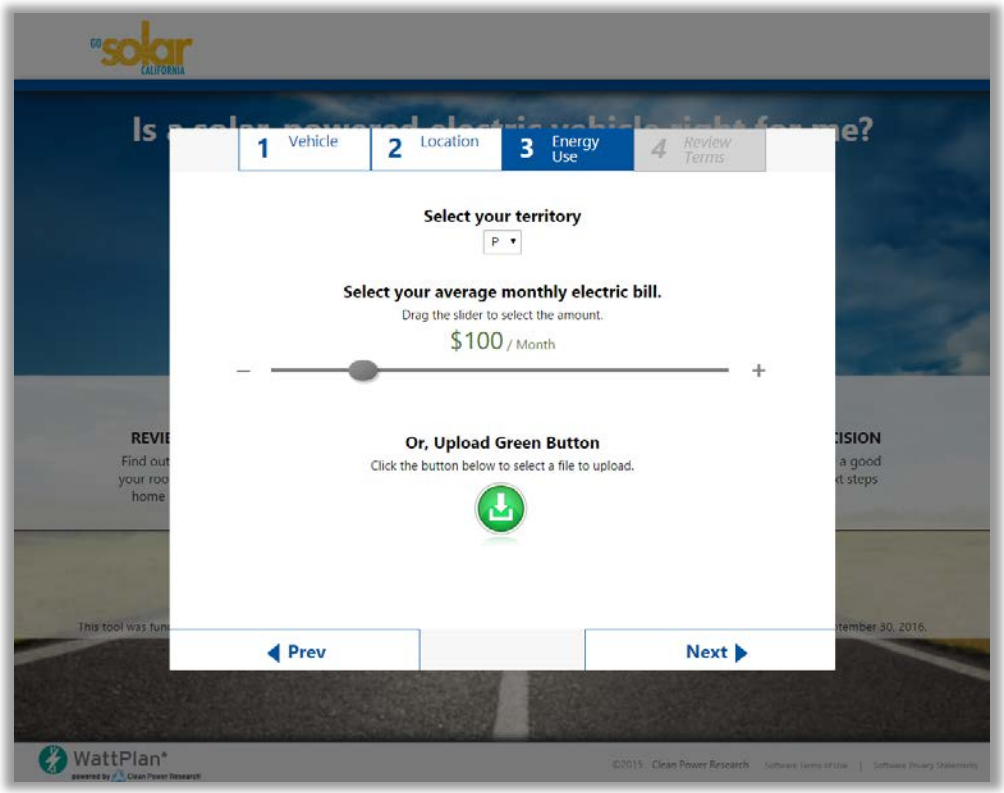



*Figure 5 – Step 3 of the Input Wizard or the Energy Use tab.*

After the user specifies which data inputs to use, WattPlan conducts detailed calculations and then presents the results in a number of personalized, understandable and approachable formats. These sections include the following:

- **Summary** section (Figure 6) complete with energy, economic, and environmental impact comparisons for the two vehicle scenarios the user selected.
- **Electric Rate Plan Comparison** (Figure 7) indicating which available electric rate offers the greatest savings potential.
- **Compare** section (Figure 8) which lays out the cost implications associated with each scenario.
- **Charge** section (Figure 9) exploring the impact of charge time and charger type (e.g., Level 1, 2, etc.) on home electricity use.
- **Range** section (Figure 10) helping users visualize the range of the selected EV on a single charge.
- **Community** section (Figure 11) presenting a map illustrating the number of solar installations and electric vehicles California residents have purchased.

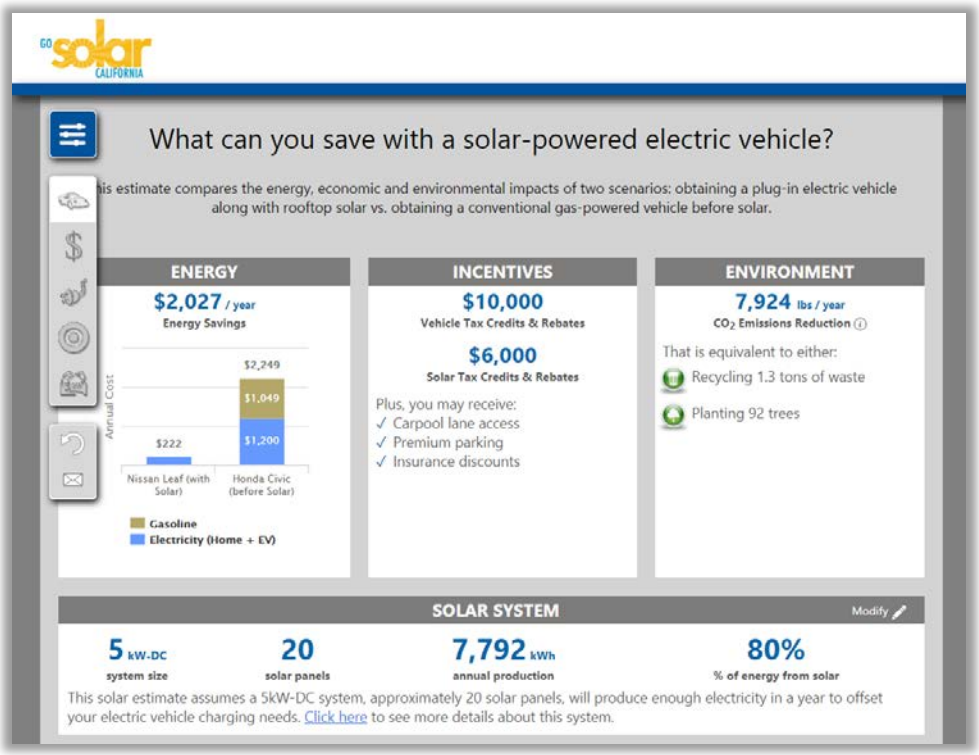



*Figure 6 –Summary page presenting data comparing the energy, economic, and environmental impacts of the two scenarios.*

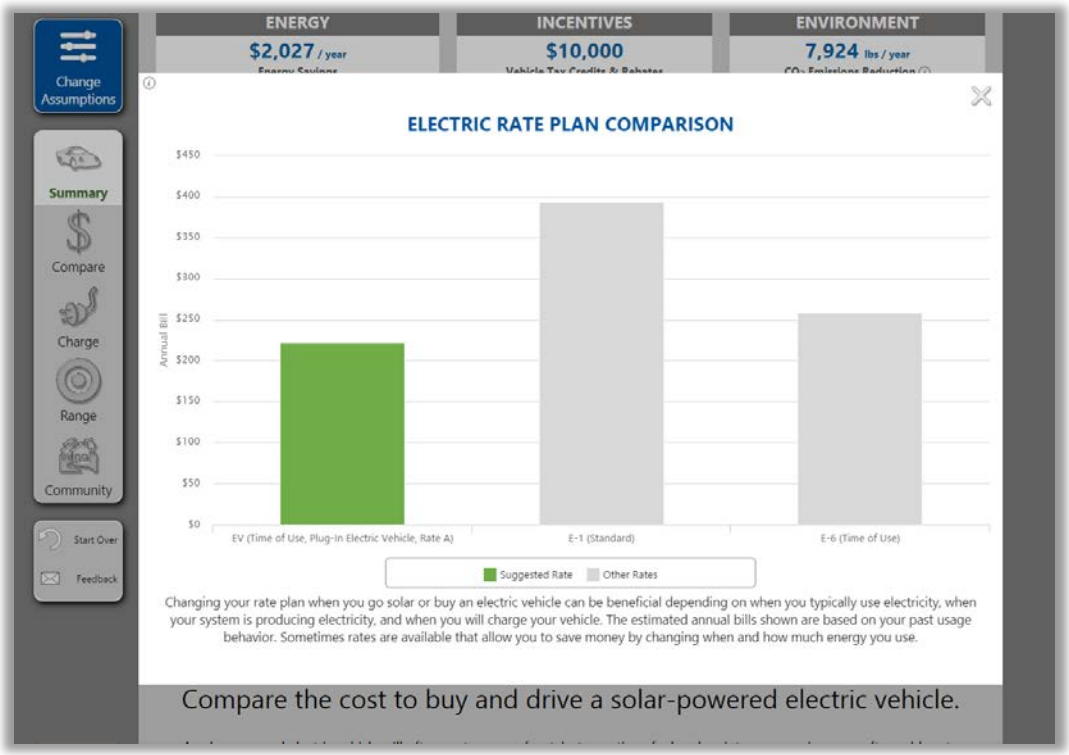



*Figure 7 – Electric Rate Plan Comparison identifies which electric rate plan offers the highest savings potential.*

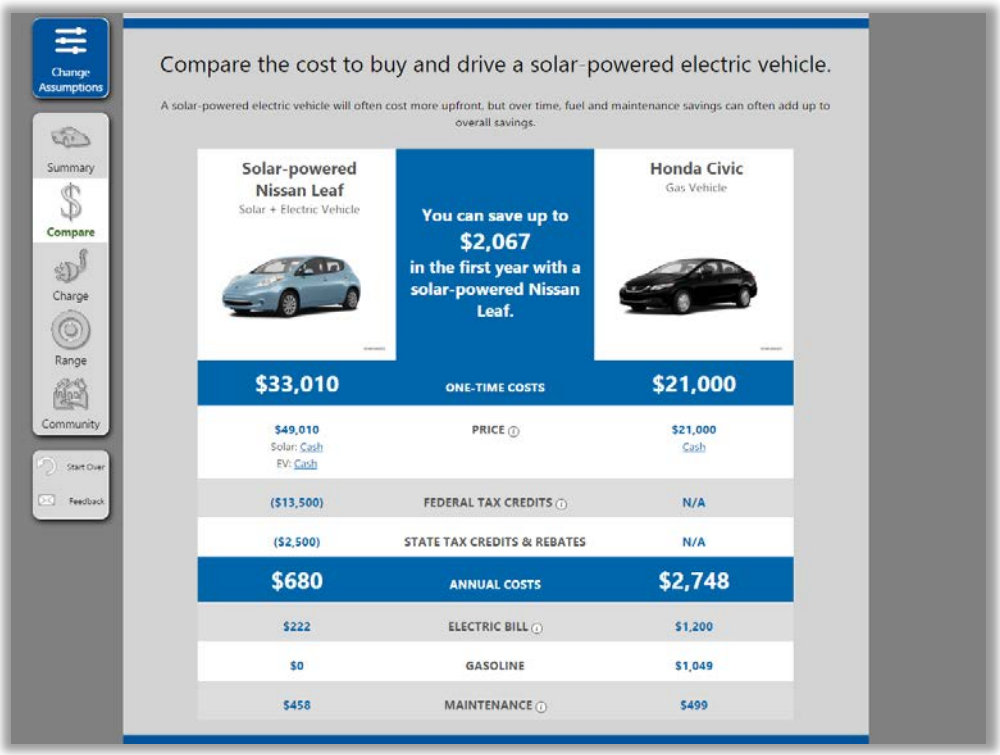



*Figure 8 – The Compare page displays various costs associated with each scenario.*

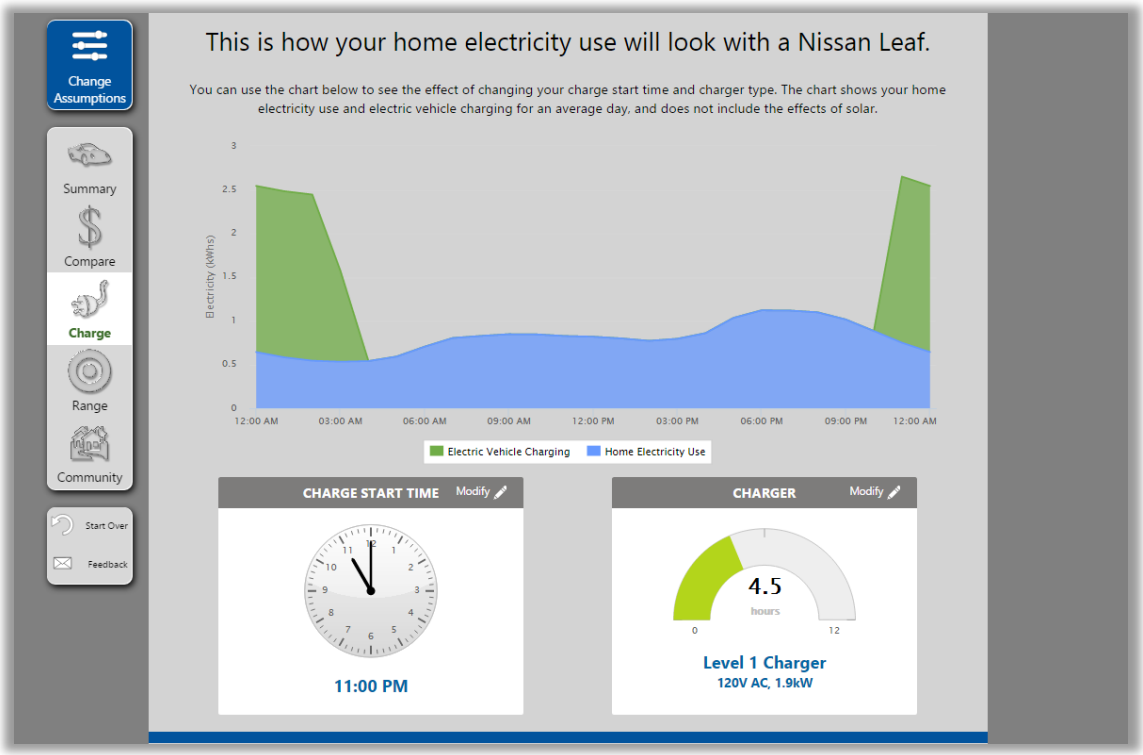



*Figure 9 – Charge section allows user to explore impact of Charge Start Time and Charge Type (i.e. Level 1, etc.) on overall Home Electricity Use.*

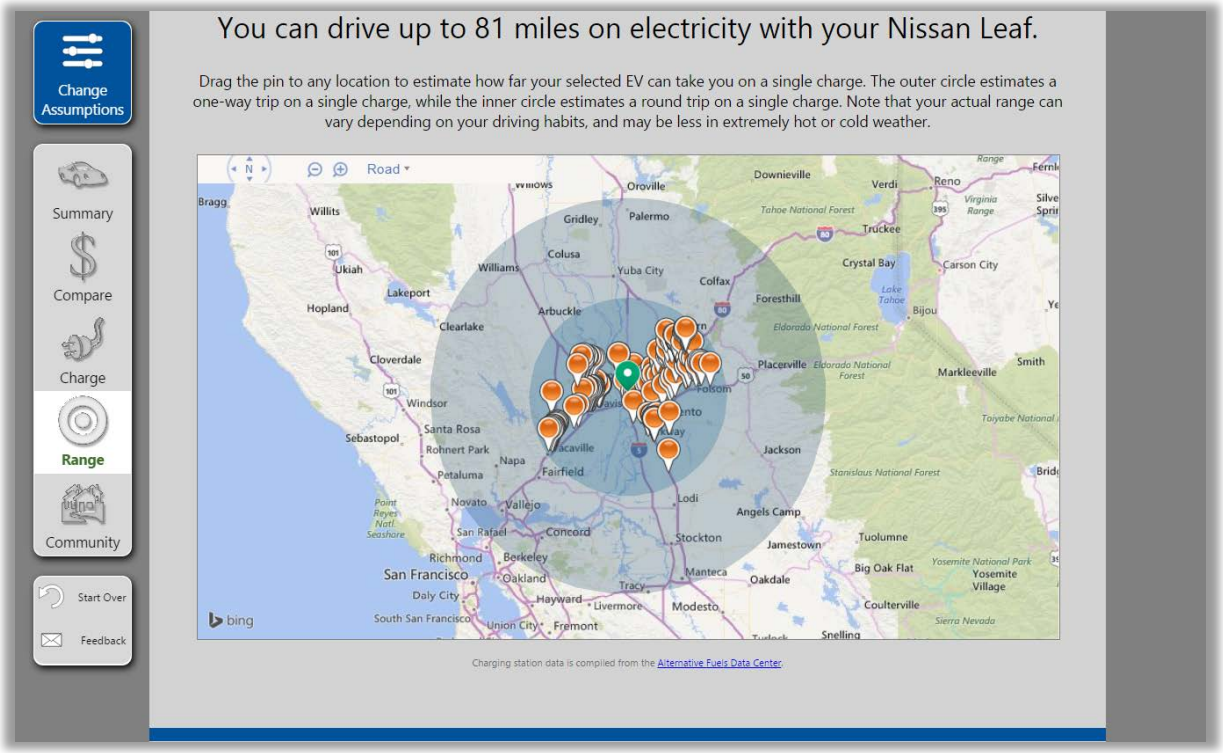



*Figure 10 – Range Section visualized estimate of EV range on a single charge (one way and round trip).*

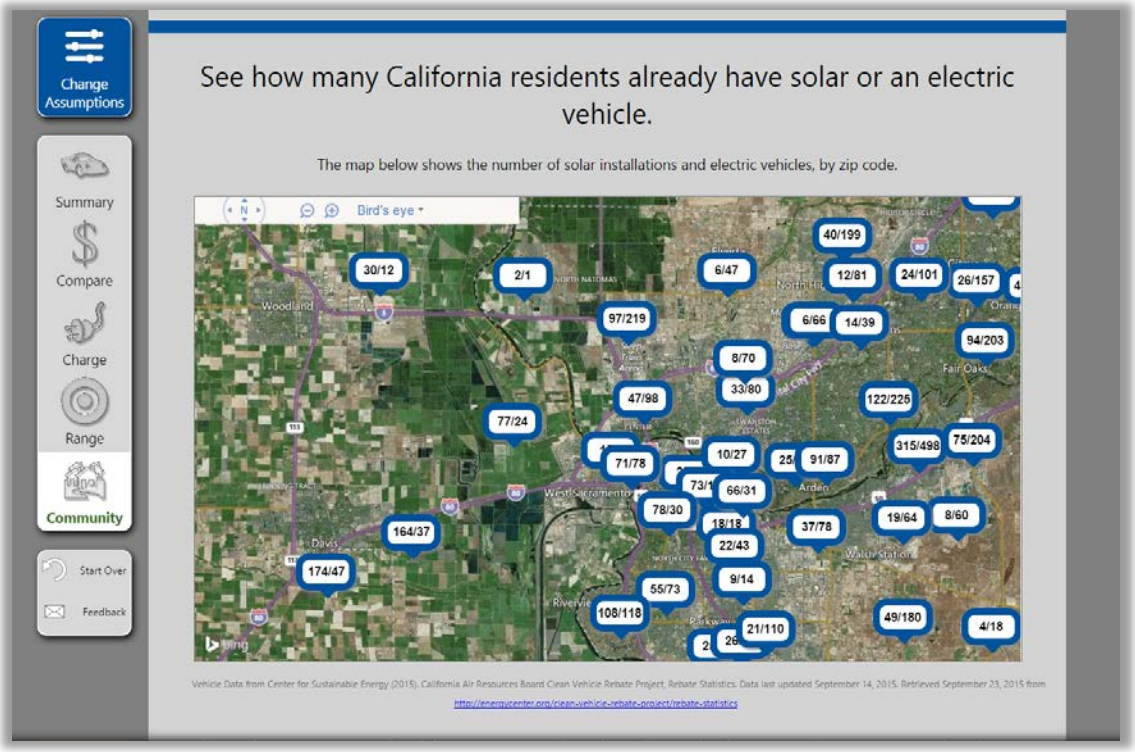



*Figure 11 – Community Section presents data on number and location of CA residents who have installed PV or own an EV.*

The user can also adjust the tool's default assumptions in a number of ways using the Change Assumptions menu. The tabs available on this menu include:

- **Utility tab** (Figure 12 – Change Assumptions Utility tab.) allows user to specify a current electric rate, turn rate optimization off and select an alternate "with solar rate" to compare, and adjust the avg. monthly bill.
- **Driving & Fueling tab** (Figure 13) includes sliders to adjust assumed driving behavior (i.e. Daily Commute and Annual Driving miles) as well as assumptions regarding charge type, charge start time, and use of public charging stations and the associated cost.
- **Vehicles tab (**Figure 14**)** where users can adjust the price of the electric and gas vehicles as well as the method of financing.
- **Solar System tab** (Figure 15) with subtabs detailing the default system, percent of energy to offset with solar, and the ability to define parameters for a custom system.
- **Solar Financing tab** (Figure 16) here the user can configure the solar system's unit price ($/Watt-DC) and select how to finance it (i.e. cash, loan, or lease).

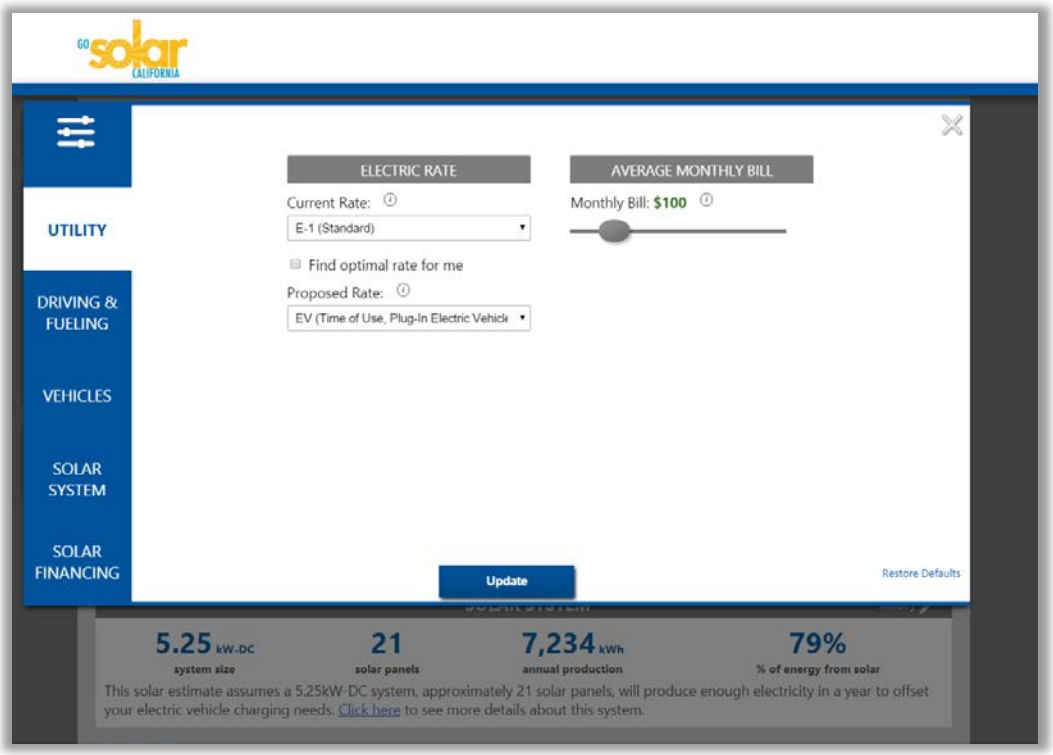



*Figure 12 – Change Assumptions Utility tab.*

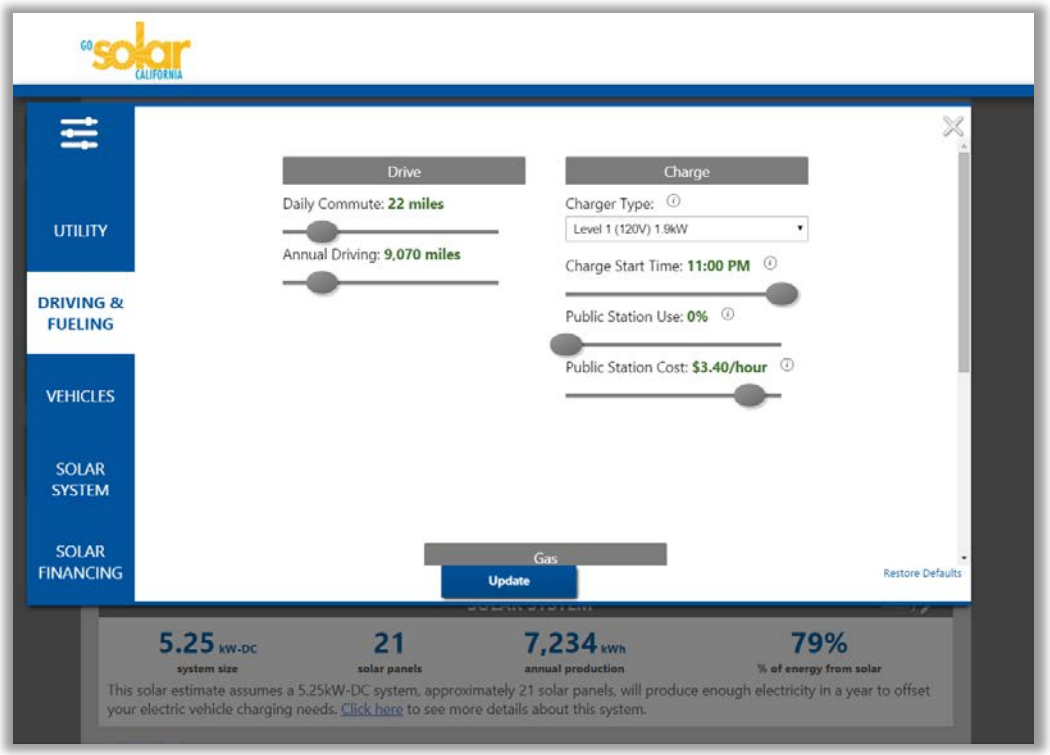



*Figure 13 - Change Assumptions Driving and Fueling tab.*

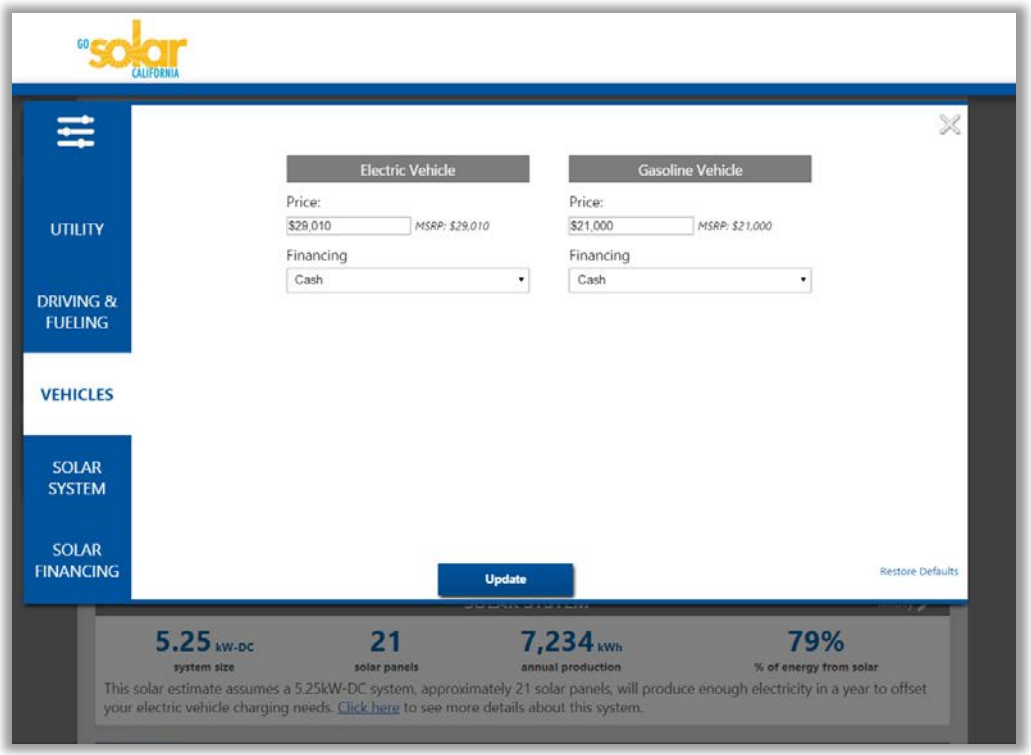



*Figure 14 - Change Assumptions Vehicles tab.*

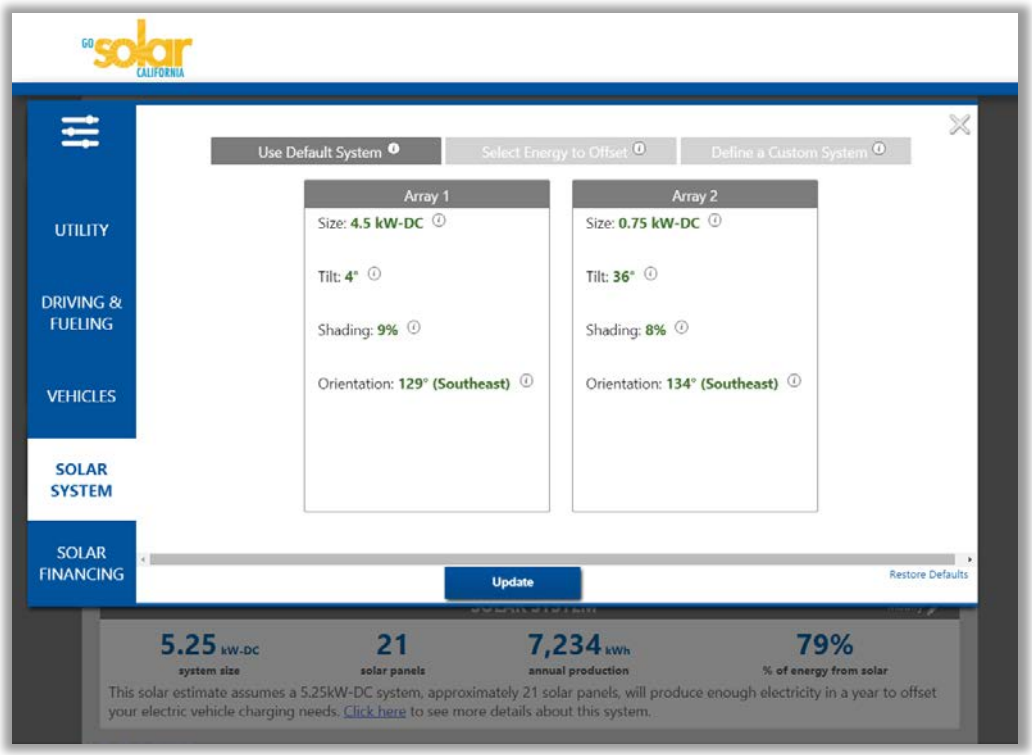



*Figure 15 - Change Assumptions Solar System tab.*

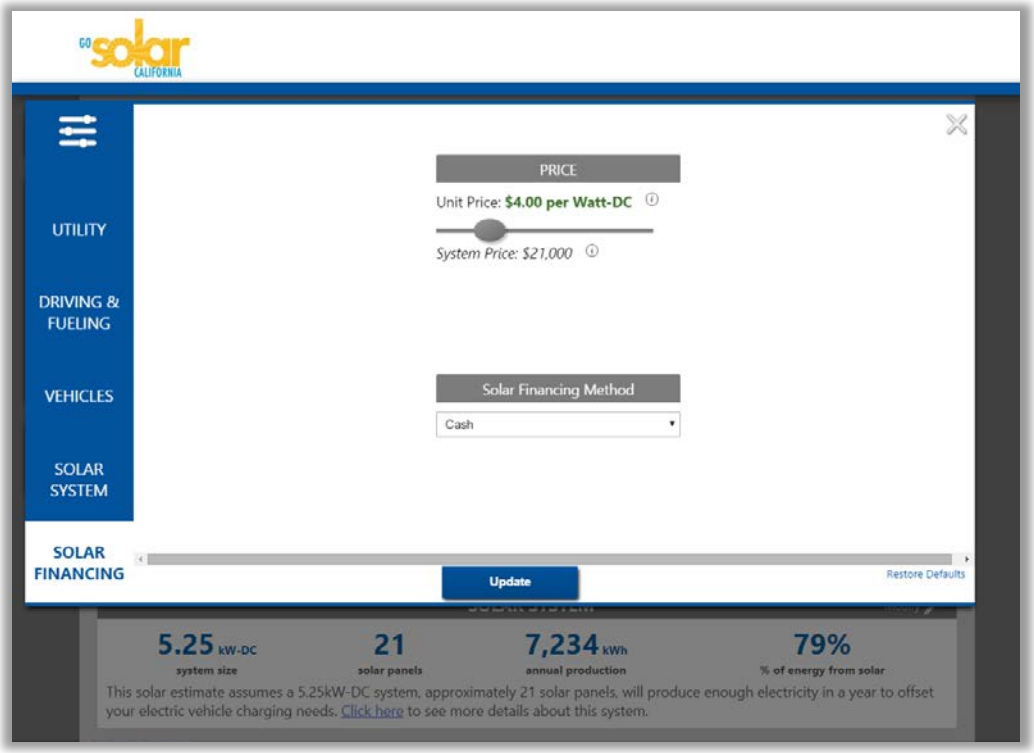



*Figure 16 - Change Assumptions Solar Financing tab.*

Google Analytics was implemented and initial click-stream information is being stored (no PII), such as, sections viewed, time lapse on each section, referral source, etc. In addition, key usage data that will allow administrators to access information such as the number of unique users in any given time period and general locational information is stored. This data will provide an understanding of and report on key metrics within the California market for the remaining duration of this service subscription.

An error alerting notification system was developed as well. This system notifies users when an error occurs and if/when possible allows the user to proceed with a reasonably positive experience. Regardless of the type and magnitude of error, a notification will be sent to CPR engineers. This error alerting system includes error finger print information, which enables the team to respond promptly and efficiently to resolve the issue and limit the number of recurrences. CPR developers have already been able to identify and fix errors through the use of this alert system.

The user interface has been optimized to be fully viewable and functional at a minimal screen resolution of 1280x800, meeting the needs of most modern desktop computer/monitors and mobile tablets. Additionally, the platform has been tested and optimized to be fully functional on Internet Explorer 10 and 11, Chrome, Firefox, and Safari 6 and 7 on Mac.

## Recommendations

CPR will continue to improve and enhance WattPlan. The business model for this product will be through software-as-a-service subscriptions to utilities. CPR is already seeing strong adoption of the WattPlan product as an online customer engagement tool for utilities to serve as the trusted energy advisor to their customers. Utilities have a strong relationship with their customers, which is currently being threatened. Tools like WattPlan can help promote their brand and position them as the advisor for all things energy related.

CPR encourages the CPUC and its associated programs to continue looking at cross-technology solutions that acknowledge the breadth of options consumers are faced with today. While this particular project focused on combining PV and EV technologies, other technologies and behaviors, such as demand controllers, storage, plug load reduction, and other energy efficiency measures could be included in a tool like WattPlan to further enhance the analysis and its ability to guide consumer energy decisions.

## Benefits to ratepayers of California

The PV+EV calculator developed for CSI, launched on September 23, 2015. An announcement was included in the California Public Utilities Commission's July/September 2015 newsletter, "Go Solar, California!" and can be found at https://csinewsletter.energycenter.org/newsletter/2015/09/91.

California ratepayers can access the PV+EV calculator and enter specific information about themselves including: their home energy consumption and driving habits, available electric rates, financing options, available roof space and solar resource, available federal, state, and local tax credits and rebates, and the potential tax implications of these incentives.

After providing this information, the customer can utilize the tool to answer complex questions. For example:

- What size PV system is necessary to accommodate a PEV?
- What electric tariffs are available and which is most economical?
- What are the differences between and implications of the various financing methods available to purchase the technology?

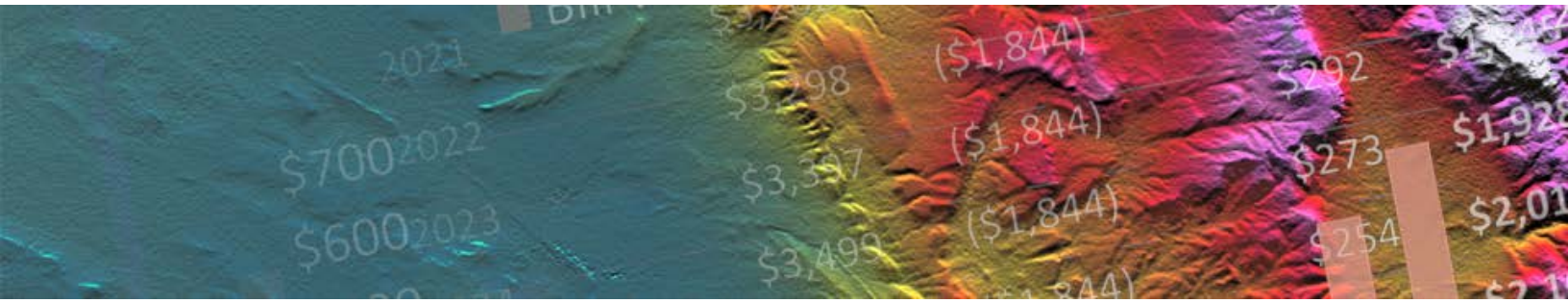
Armed with confidence, the answers to these questions, and a newfound understanding of each technology, consumers are better prepared to make the complex purchase decision to install solar and purchase an electric vehicle. Two innovative technologies that offer consumers the potential to save energy and money.

# Appendix A

# Product Manual: WattPlan Vehicles

# Product Manual: WattPlan Vehicles

*This document describes the features and functionality of the WattPlan service as of the date listed in the footer below. As a multi-tenant software service, customers should expect the service to be improved and enhanced over time with benefits accruing to all customers. As part of a continued effort to deliver great products to customers, over time, new innovations and customer feedback will drive the evolution of the features and functionality described in this document.*




Clean Power Research®

# Contents



# Product Overview

WattPlan™ is designed to make electric vehicle (EV) decision-making process as simple as possible and communicate the benefits of solar combined with electric vehicles. Users can quickly and remotely estimate if an electric vehicle is right for them and assess their home's or office's potential for rooftop solar. The entire estimation process has been engineered to require little or no information from the user, placing these complex energy decisions within reach for all utility customers through a very simple, step-by-step user interface.

WattPlan guides users through the analysis one step at a time, highlighting the most important information needed to make a decision. Upon arriving at WattPlan, the user is asked to provide their home address, an estimate of their average monthly electric bill, and to select two vehicles (a conventional and an EV) to compare. From this information, WattPlan will perform a detailed analysis of electric bill effects and financing options. Customers who want to dive deeper can access more detailed information with the click of a button, and dynamically adjust parameters of vehicles and financing methods. Personal analyses are presented in three sections:

1) **Summary** – WattPlan first presents the most interesting elements of owning an electric vehicle: the annual fuel savings, the amount of available incentives, and environmental impacts. In addition, several less tangible benefits of owning an electric vehicle are highlighted as well, such as carpool lane access, premium parking, and reduced maintenance visits.
2) **Compare** – Here the user can compare economics for a conventional and electric vehicle. This is presented in a step by step fashion. Purchase, Electric Bill, and Fuel Cost illustrate the upfront cost, the average annual electric bill, and the average annual fuel cost for the vehicles being compared. Here the user can access more information like the total savings and total fuel savings over the lifetime of the two vehicles.
3) **Charge** – Information on how an EV will affect electricity use is critical to successful EV ownership. This section provides a detailed look at electricity use throughout the day, and educates the user on when they should be charging their EV to realize the maximum financial benefit.

# Methodology

## EV Load Modeling

The EV load profile is dependent on three components: charge capacity, duration, and start time. With these three elements known, a load profile can be constructed by first determining how many intervals the vehicle will charge at full capacity.

$$\#\ of\ intervals = Duration[hrs] \times \frac{IntervalLength[min]}{60\left[\frac{min}{hr}\right]}$$

With this approach a load profile with *IntervalLength* of 1 hour, ½ hour, or ¼ hour can be constructed. The load (kW) for each interval beginning with the start time and ending with start time plus the number of whole intervals multiplied by interval length should be set equal to Capacity (described below). The remaining fractional component of the number of intervals should be multiplied by Capacity to find the load magnitude for the final interval.

### *Charge Capacity*

Charge capacity is broken into 2 categories, Level 1 and Level 2, which corresponds to the voltage at which charging is performed (120V and 240V respectively). Charging level is configurable with discrete options for capacity if Level 1 or 2 is selected:

| Level | Voltage [V] | Capacity [kW] |
|---|---|---|
| Level 1 | 120 | 1.4 |
| Level 1 | 120 | 1.9 |
| Level 2 | 240 | 3.3 |
| Level 2 | 240 | 6.6 |
| Level 2 | 240 | 7.7 |
| Level 2 | 240 | 9.6 |

### *Charge Duration*

Charge duration is determined by calculating the required energy use per day.

$$energyUse[kWh/day] = \frac{miles}{year} \times \frac{kWh}{100\ miles} \times \frac{year}{365\ days}$$

$$Duration[hours] = energyUse \times \frac{1}{Capacity[kW]} \times \frac{1}{ChargerEfficiency}$$

If *energyUse* is greater than the vehicle battery capacity, then *energyUse* when calculating *Duration* is equal to the battery capacity of the EV, and the additional kWh/day are assumed to be charged at a price for public charging. This calculation is repeated for city and highway miles.

## Solar Analysis

WattPlan will be able to configure a system to fit the user's roof based on LiDAR data for their home address (which they entered as part of the daily commute upon entering WattPlan Vehicles). The system will be sized to offset the user's EV annual energy consumption, and separate financing will be able to be used for the solar system and the electric vehicle.

## Electric Bill Impacts

The PowerBill® API bill calculation from Clean Power Research is used to calculate current and proposed bills (without and with an EV). Proposed load is the current load, plus the output from the EV load simulation described above. WattPlan displays the change in electric bills for a conventional vehicle vs an EV.

## Fuel Cost Impacts

WattPlan communicates annual fuel cost savings to the user based on the difference between annual fuel expenses for the chosen conventional vehicle.

$$Conventional: \quad FuelCost[\$] = \frac{miles}{year} \times \frac{gal.}{mile} \times \frac{cost[\$]}{gal.}$$

The number of miles per year is based on the distance of the user's typical daily commute. Both the electric bill prices and the cost per gallon of gasoline have a fuel price escalation (%/year) for calculating future year cash flows. Vehicle efficiency is determined using the EPA weighted average fuel economy for city vs highway miles for the chosen vehicle.

## Financing Methods

WattPlan supports both cash and loan financing for vehicles, and cash, loan, and lease financing for rooftop solar. As mentioned, financing for vehicles can be chosen separately for solar. For example, a user can choose to finance both solar and their vehicle with a loan, or they can choose to purchase the vehicle outright and still use a loan to finance their solar system. Financing takes into account all applicable tax credits and rebates, any additional cost for vehicle charging equipment, and tax effects of loan payments for secured loans.

## Environmental Impacts

Environmental calculations are based on state level EPA emission factors and a transmission and distribution efficiency of 94%. Emissions are calculated for both the electric vehicle and the conventional vehicle.

## Incentives

Incentives include monetary and "intangible" incentives such as HOV lane access, preferred parking, and reduced number of trips to mechanic/dealer for maintenance. Monetary incentives should include the state level incentives, and local incentives, in addition to the federal tax credit. The Federal Plug-In

Electric Drive Vehicle Credit provides $2,500 plus $417 for vehicles with battery capacity in excess of 5 kWh and $417/kWh for every additional kWh over 5.

$$batterySize[kWh] = \frac{combE[kWh\ per\ 100\ miles]}{100[miles]} \times range[miles]$$

## Rate Optimization

WattPlan EVs calculates the cost of an electric vehicle for different rate structures, and then suggest the user switch to the cheapest rate structure.

## Community Information / Market Statistics

WattPlan EVs is capable of displaying a map of charging stations in the user's area. Also in this section will be some summary statistics for how many EVs have been sold in the user's state and the environmental impact of replacing that same number of internal combustion engine vehicles.