Profitability and Environmental Benefit of Providing Renewable Energy for Electric Vehicle Charging

by

Ian Andrew Nienhueser

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Graduate Supervisory Committee:

Yueming Qiu, Co-Chair
Bradley Rogers, Co-Chair
Narciso Macia

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ABSTRACT

This study evaluates the potential profitability and environmental benefit available by providing renewable energy from solar- or wind-generated sources to electric vehicle drivers at public charging stations, also known as electric vehicle service equipment (EVSE), in the U.S. Past studies have shown above-average interest in renewable energy by drivers of plug-in electric vehicles (PEVs), though no study has evaluated the profitability and environmental benefit of selling renewable energy to PEV drivers at public EVSE. Through an online survey of 203 U.S.-wide PEV owners and lessees, information was collected on (1) current PEV and EVSE usage, (2) potential willingness to pay (WTP) for upgrading their charge event to renewable energy, and (3) usage of public EVSE if renewable energy was offered. The choice experiment survey method was used to avoid bias known to occur when directly asking for WTP. Sixty percent of the participants purchased their PEVs due to environmental concerns. The survey results indicate a 506% increase in the usage of public pay-per-use EVSE if renewable energy was offered and a mean WTP to upgrade to renewable energy of $0.61 per hour for alternating current (AC) Level 2 EVSE and $1.82 for Direct Current (DC) Fast Chargers (DCFC). Based on data from the 2013 second quarter (2Q) report of The EV Project, which uses the Blink public EVSE network, this usage translates directly to an annual gross income increase of 668% from the original $1.45 million to $11.1 million. Blink would see an annual cost of $16,005 per year for the acquisition of the required renewable energy as renewable energy credits (RECs). Excluding any profit seen purely from the raise in usage, $3.8 million in profits would be gained directly from the sale of renewable energy. Relative to a gasoline-powered internal combustion engine passenger

vehicle, greenhouse gas (GHG) emissions are 42% less for the U.S. average blend grid electricity-powered electric vehicle and 99.997% less when wind energy is used. Powering all Blink network charge events with wind energy would reduce the annualized 2Q 2013 GHG emissions of 1,589 $\text{metric tons } CO_2/yr$ to 125 kg CO_2/yr, which is the equivalent of removing 334 average U.S. gasoline passenger cars from the road. At the increased usage, 8,031 $\text{metric tons } CO_2/yr$ would be prevented per year or the equivalent of the elimination of 1,691 average U.S. passenger cars. These economic and environmental benefits will increase as PEV ownership increases over time.

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LIST OF ABBREVIATIONS

Abbreviation

2Q – Second Quarter

AC – Alternating Current

CV – Conventional Combustion Engine Vehicle

CVB – Conventional Combustion Engine Vehicle Buyer

DC – Direct Current

DCFC – Direct Current Fast Charger

EV – All-Electric Vehicle

EVSE – Electric Vehicle Service Equipment

GHG – Greenhouse Gas

GPP – Green Pricing Program

HEVB – Hybrid Electric Vehicle Buyer

PEV – Plug-In Electric Vehicle

PEVB – Plug-In Electric Vehicle Buyer

PHEV – Plug-In Hybrid Electric Vehicle

PV – Photovoltaic

REC – Renewable Energy Credit

REF – Renewable Energy Fraction

WTP – Willingness To Pay

CHAPTER 1

INTRODUCTION

Transportation in the developed world is powered predominantly by liquid fuels refined from petroleum. In the U.S. for example, 97% of transportation is powered by petroleum (US Energy Information Administration, 2014). The high energy density and abundance of these fuels have made them a very effective and relatively affordable transportation energy source. However, motivations for finding alternate sources of energy for powering transportation are numerous, including economic security, mitigation of anthropogenic climate change, lessening military conflict in the oil-rich parts of the world, and reducing risk to human health, ecological damage and environmental contamination posed by vehicle exhaust, hydrologic fracturing and oil transportation. There are a number of technologies currently at various stages of research and development with the ability to supplement or replace petroleum with a transportation energy source that is renewable, reduced in GHG emissions, and economically feasible. The most currently developed of these technologies include biofuels, hydrogen fuel cells, and PEVs powered with renewably generated electricity.

Each of these technologies has its benefits and drawbacks. Most biofuels offer a drop-in replacement liquid fuel requiring little or no modification of the current internal combustion engine technology and fueling infrastructure. However, the land, water, fertilizer, and energy requirements limit feasibility, energy gain, and GHG emission avoidance of biofuels for most feed stocks, for supplementing a majority portion of transportation energy (Clarens, et al., 2010). Algae differs from most feed stocks in that it grows more densely and on inarable land. In comparison to corn, canola and switchgrass, only algae is can be grown at a high enough annual energy output per unit land area to meet U.S. transportation needs on less than 70% of U.S. arable land (Clarens, et al., 2010), the U.S. having more arable land per capita than most developed nations. While algae is a feed stock with great potential, with current knowledge and technology, algae biofuel production is estimated at a 6% net energy gain (Clarens, et al., 2010) and a cost of $10.87 - $13.32 per gallon (Sun, et al., 2011). Corn ethanol and soy bean biodiesel currently supplement 5% of U.S. land transportation fuel (US Energy Information Administration, 2014). However corn ethanol has a net energy gain estimated at 22% and an estimated 27% GHG reduction (Clarens, et al., 2010).

While the prices remain high, several automotive manufactures plan to begin leasing hydrogen fuel cell based vehicles in 2015. The hydrogen for these vehicles can be sourced from natural gas, electrolysis of water. Relative to gasoline, sourcing from natural gas results in a 21% life cycle GNG reduction, while water electrolysis with grid electricity increases GHG emissions by 25% (US Argonne National Laboratory, 2014). Electrolyzing with electricity generated by renewables reduces GHG emissions by greater than 99% (US Argonne National Laboratory, 2014).

With present technology, all-electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) collectively, plugin electric vehicles (PEVs) offer a cost-effective means of transportation with significantly reduced GHG emissions and in the U.S., powered predominantly by domestic energy sources. EVs priced for the mass market such as the Nissan Leaf, Ford Focus EV and Smart Fortwo ED are currently limited to a driving range of about 60-85 miles per charge, with high end EVs such as the Tesla Model S traveling greater than 250 miles per charge. PHEVs such as the Chevy Volt and Ford C-

Max Energi provide 20 – 40 miles of electric driving per charge in addition to a gasoline-powered driving range, which is most often similar to conventional internal combustion engine vehicles (CVs). For the majority of U.S. drivers, PHEVs offer enough driving range for daily commutes, while offering extended range when needed. Charge times for PEVs are typically 3 to 6 hours on a 240 volt AC Level 2 EVSE. While most EVs can also charge to about 80% capacity in 30 minutes on DCFCs. Powered by the average U.S. grid electricity mix, PEVs electric energy life cycle emissions are approximately two thirds that of gasoline powered transportation (US Argonne National Laboratory, 2014), while the energy cost is about a third that of gasoline. Powered by renewable energy sources, such as wind or solar energy, the energy life cycle GHG emissions of PEVs amount to less than 1% that of gasoline and with an energy cost still well below that of gasoline (US Argonne National Laboratory, 2014).

This study evaluates the potential for profitability and environmental benefit available by providing renewable energy to electric vehicle drivers at public stations, also known as electric vehicle supply equipment (EVSE) in the U.S. Through an online survey of U.S.-wide PEV owners and lessees the following information was collected:

1. Stated willingness to pay (WTP) for upgrading their pay-per-use charge event at a public EVSE to renewable energy from wind or solar sources
2. Would the availability of renewable energy at such EVSE change their EVSE usage frequency
3. How likely would they choose a EVSE offering renewable energy over one that does not

A case study providing profit and environment benefit available to one of the largest U.S. public PEV charging companies is also included.

CHAPTER 2

BACKGROUND

A comprehensive literature review revealed no public studies on the willingness of PEV drivers to pay for renewable energy or on the resultant profitability and environmental benefit of providing renewable energy for PEV charging at public pay-per-use EVSE.

Demand for Renewable Energy and Renewable PEV Charging

The few studies that have been conducted on the subject have found PEV drivers have a higher-than-average interest in renewable energy. A survey of about 1,400 PEV owners in California (California Center for Sustainable Energy, 2012) found that 39% of the participants had a photovoltaic (PV) solar system on their home, with another 17% planning on installing PV in the next year, showing demand for renewable energy. Of those with PVs, about 50% have sized their system to meet the energy demand of their vehicle, while of those who have not done so already, 60% of them plan to expand their PV in the next year to account for their PEV energy needs, showing demand for charging PEVs with renewable energy.

A recent U.S.-wide survey (Krupa, et al., 2014) of about 1500 individuals, consisting of three populations of recent vehicle buyers: CV buyers (CVBs), hybrid electric vehicle buyers (HEVBs) and PEV buyers (PEVBs). With typical pricing for each attribute, surveyees were asked to design the next vehicle they would purchase, then to design a home energy source and finally after being introduced to the possibility of powering a PEV with renewable energy, they were given an opportunity to redesign both the vehicle and energy source. Krupa et al. found increased use of renewable energy with electrification of the participants purchased vehicle, with 18% of CVBs, 44% of HEVs, and 41$ of PEVBs currently powering their home with renewable energy, respectively. After the introduction to renewable PEV charging, Krupa et al. found the following percentages of participants chose an energy source and vehicle combination allowing for renewable vehicle charging: CVBs-31%, HEVBs-53%, and PEVBs-86%. Krupa et al. also found a 22% increase in PEV demand with the introduction to renewable PEV charging. This study shows a strong interest in charging with renewable energy, particularly among PEV owners.

WTP for public PEV charging

The stated mean Californian PEV drivers WTP for public charging without renewables from the earlier mentioned survey is provided in Table 1 (California Center for Sustainable Energy, 2012). The direct ask surveying method was used to obtain these values.

Table 1. Stated Public Charging WTP

Charging Frequency	Mean AC Level 2 EVSE WTP ($/hr)	Mean DCFC WTP ($/30 min)
3 or more days per week	$0.80	$3.70
1 or 2 days per week	$1.17	$5.20
Less than 1 day per week	$2.36	$9.28

Current prices charged at public EVSE provide another source of pricing information. The prices from the largest U.S. public charging providers and U.S. average residential utilities are shown in Table 2 (Blink, Inc., 2014) (The Long Tail Pipe, 2014). This pricing is closest to the “less than 1 day per week” and “1 or 2 days per week” values from the California Center for Sustainable Energy study, for AC Level 2 and DCFC respectively. Within this table, where necessary to convert energy-based pricing to time-based pricing, a 6 kW charge rate is used for AC Level 2 EVSE and a 28 kW charge rate for DCFCs, each of which is typical of today's PEVs using the specified charging technology.

Table 2. Public Charging Pricing by Public EVSE Providers in 2014 dollars (*based on 6 kw charge rate, **based on 28 kw charge rate)

Charging Source	AC Level 2 EVSE Price ($/hr)	DCFC Price ($/30 min charge)
Blink before 9/2014	$1.00	$5.00
Blink starting 9/2014	$2.40	$6.99
ChargePoint	$2.94*	$6.86**
Sigma Charge	$2.94*	$6.86**
U.S. Residential Utility Average	$0.78*	$3.65**

At the pre-9/2014 prices, Blink found their nationally distributed customers did 9% of their charge events at public AC Level 2 EVSE and 5% at public DCFCs. The remaining 86% of the charge events occurred at their personally owned EVSE, paying utility electricity rates. This usage amounts to 77,640 public charge events on 2,762 public EVSE in the second quarter of 2013 (Ecotality North America, 2013).

Sources of Renewable Energy for EVSE

The three most plausible means of acquiring renewably generated electricity for use at public EVSE include on-site solar, utility green pricing programs, and renewable energy credits (RECs). While on-site solar is good for marketing, a degree of engineering and installation is required at each site. Upfront cost, loans or long-term solar lease contracts would also be required. This option also does not offer a means to choose how much renewable energy is produced each month. The amount of solar electricity generated could either exceed or fall short of meeting the renewable charging demand.

Local utility green pricing programs (GPP) avoids the installation costs and long term commitment. However, using GPPs for a nationally distributed EVSE network would require signing up for these programs and purchasing from tens to hundreds of different utility companies, while only about half the electric utility customers in the U.S. have access to a GPP (National Renewable Energy Laboratory, 2013), making this option unavailable in some locations.

Renewable energy credits are used to track the trade of renewable energy in the U.S., including that energy sold in GPPs. Purchasing RECs directly from REC brokers, wind farms, or solar fields, would allow a public EVSE company to use its nationwide renewable energy demand to negotiate a lower price and to make a periodic purchase from a single supplier in a quantity matching usage, without making any changes with their utility companies (National Renewable Energy Laboratory, 2013). Of the renewable energy sold in the U.S., 63% is purchased as RECs separate from the purchase of electricity (National Renewable Energy Laboratory, 2013). The majority of these REC sales are to corporations with an interest in reducing their environmental impact and improving their corporate image, including Whole Foods, Intel, Walmart and others. Representing the renewable qualities of renewable energy, RECs are a third party certified, paper commodity used to track the purchase of renewable energy from the generator to the customer. RECs are necessary since the electric grid cannot physically direct electricity from a specific generator to a specific customer. RECs are also available at a low cost, typically about $0.001 per kWh for nationally sourced wind energy (National Renewable Energy Laboratory, 2013).

For these reasons, RECs are used in the case study of profitability in this thesis.

CHAPTER 3

APPROACH

Surveys

Data were gathered by surveying current owners and leases of PEVs within the U.S. The names and postal addresses of PEV owners and leases were purchased from a mail marketing company that obtains their records from the Department of Motor Vehicles in states where this information is available. The company also purchases information from automotive insurance companies and automotive repair shops, amongst other commercial sources.

Postcards requesting participation in an online survey about electric vehicles and renewable energy were sent to 1,500 individuals. Of these postcards, 28 were returned as undeliverable. Two hundred and three respondents completed at least the first 20 questions regarding WTP, representing a 13.5% response rate, while 181 respondents answered every question.

The survey was developed and administered with the online survey tools provided by Qualtrics. The 55 question survey collected information on

- PEV usage
- Public EVSE usage
- Motivations
- Demand and WTP for renewably powered public PEV charging
- Demographics

Within the surveys, information was gathered for two formats of offering renewable energy. Both every charge being sourced renewably and offering renewable energy as an optional upgrade were examined. The survey referred to renewable energy coming from wind and solar sources.

Choice Experiment

WTP was assessed through both directly asking and with a choice experiment model. Directly asking for WTP has been shown to generate biased results, such as overstating prices due to prestige effects or understating because of customer collaboration (Breidert, 2005). We used the choice experiment method for a more accurate assessment of the WTP for renewable energy charging. The method more closely simulates a purchase decision by asking the surveyee which of two product options they would choose to buy (McFadden D. , 1986). With this method, each option has a specified price, and purchasing neither is also an option. The WTP for the individual attributes of the product are assessed independently by varying the attributes of interest and pricing presented, while holding any other attributes constant.

For our survey, the attribute being assessed is the addition of renewable energy to public pay-per-use PEV charging. The surveyees were presented with various fractions of their charge being powered by renewably generated electricity from sources such as wind turbines and solar systems. The fraction of renewable energy was varied from 0% to 100%, with prices for the charge varying from $1 per hour to $1.24 per hour for AC Level 2 charging and $5.00 to $5.60 per 30 minute charge for DC fast charging. These prices were chosen based on the Blink network prices, REC prices, and the results of a pilot-scale survey of 19 individuals at public EVSE in the Phoenix, Arizona metropolitan area. In the full-scale survey, 10 such Choice Experiment Model questions were asked for AC Level 2 charging and 10 for DCFC. The order of the Choice Experiment questions was randomized.

The complete survey is included in Appendix A.

Economic Model

The commonly used discrete choice modeling frame work was applied in this work, assuming that the surveyees base their purchasing decisions on maximizing utility. The Random Utility Model (McFadden, 1974) describes the utility *U* provided by a product option *j* has to an individual *i* as the sum of the observable component *V* and the unobservable ε:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

To estimate the choice experiment model WTP we used an observable utility function including only the attributes presented in choice experiment questions:

$$V_{ij} = \beta_{i,REF} REF_{ij} + \beta_{Price} CEPrice_{ij}$$

$$\beta_{i,REF} = \beta_{REF} + \mu_{i,REF}$$

where β_{REF} is a population mean coefficient for REF and $\mu_{i,REF}$ represents the stochastic deviation of the individual's preference from the population mean. REF_{ij} is the renewable energy fraction, β_{Price} is the coefficient for $CEPrice_{ij}$. $CEPrice_{ij}$ is the product alternative price. Several other models of the observable utility were applied to explore the possible correlations with characteristics of the surveyees, by including or excluding terms for demographics and current charging habits.

We analyzed the CE results using the mixed logit model, which allows the random components of the choice alternatives to be correlated and takes into account the repetitive nature of CE responses (Greene, 2008). This method has been found effective for such discrete experiment data (McFadden & Train, Mixed MNL models for discrete responce, 2000).

WTP for a renewable energy premium on a one unit change in renewable energy faction (REF) be can calculated from the marginal rates of substation between the REF and the price. With the linear utility function we have applied, the marginal rate of substation between these attributes is the ratio of their coefficients. The WTP a renewable energy premium is:

$$WTP = -\frac{\frac{\partial V}{\partial REF}}{\frac{\partial V}{\partial CRPrice}} = -\frac{\beta_{REF}}{\beta_{Price}}$$

The standard deviation of the estimated WTP can be estimated from the standard deviation of the stochastic coefficient $\beta_{i,REF}$.

CHAPTER 4

RESULTS AND DISCUSSION

Survey results

The surveyed demographics of the study sample indicate PEV drivers are predominantly male, aged 30 - 69, and educated to the bachelor's level or greater, with household incomes over $70,000, as shown in Figure 1. These demographics match fairly well with those of the PEV owner population as provided by California Center for Sustainable Energy, 2012 and ECOtality, Inc., 2013, as shown in Table 3. Neither of these surveys was focused on renewable energy, providing a low likelihood of a sampling bias for an interest in renewable energy. However, the California study and the survey findings of this thesis clearly reveal a high interest in renewable energy amongst PEV owners, relative to the general population (Center for Sustainable Energy, 2014) (U.S. Energy Information Administration, 2012).

Sixty-two percent of the respondents stated that they own or lease a PHEV, while the other 38% have a PHEV, as shown in Figure 2. Of the households surveyed, 72% own two to three vehicles. For 12% of households, their PEV is their only vehicle. Four percent of households own or lease an EV as their only vehicle. The dominant motivations for purchasing PEV include environmental reasons, fuel cost savings, energy independence and new technology interest, as shown in Figure 3. Looking at these top four motivations, 60% gave environmental reasons as their primary or secondary reason. This value is 52% for fuel cost savings, 38% for energy independence and 26% for new technology.

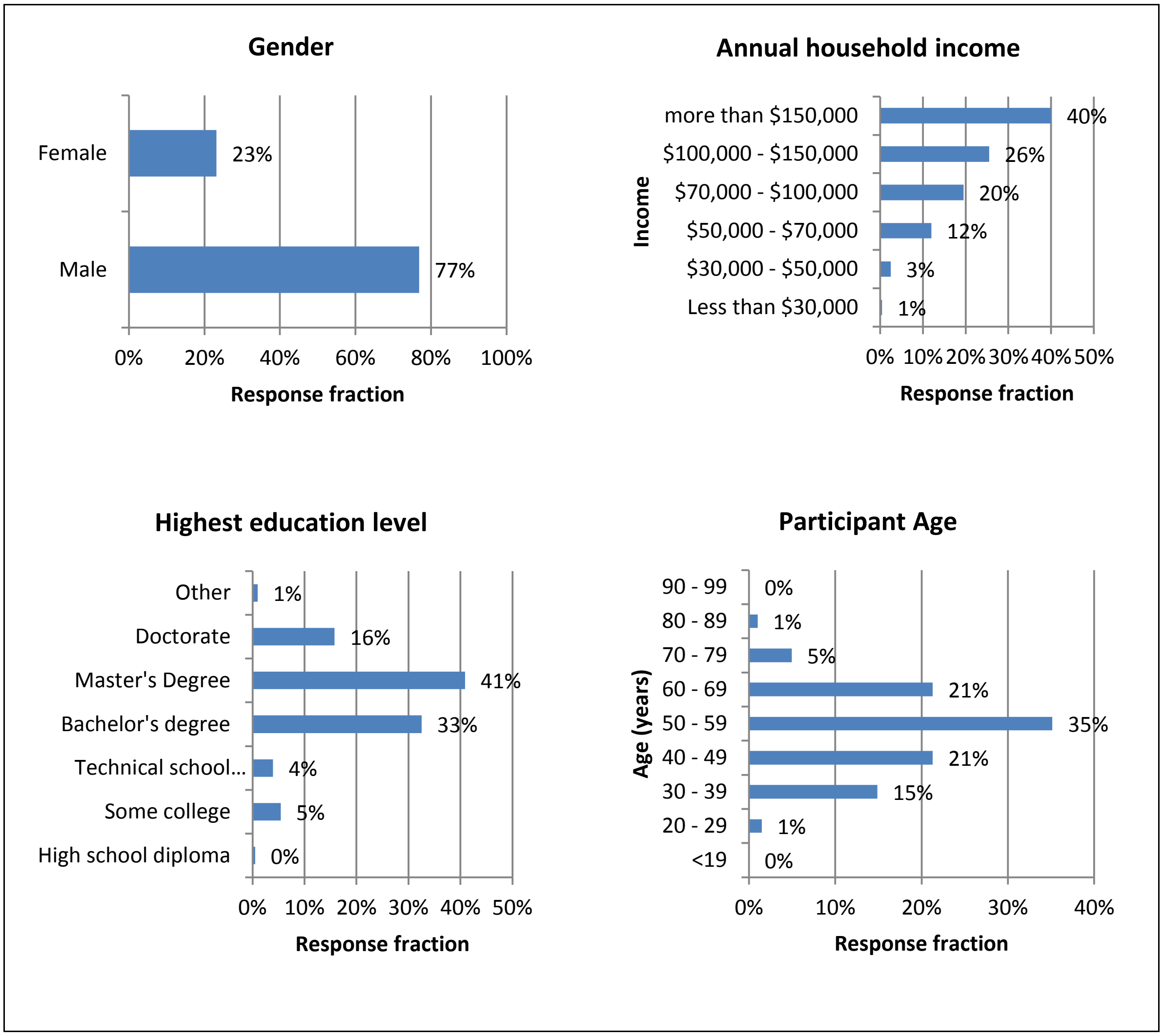

Figure 1. Participant Demographics

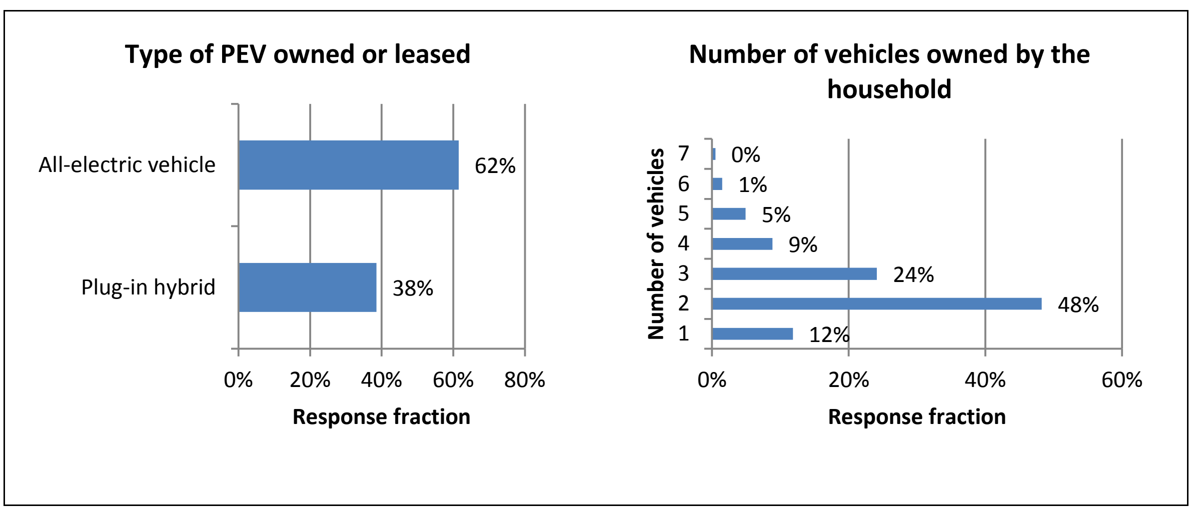

Figure 2. Vehicle Ownership / Lesseeship

Table 3. Demographics and Residential PV Comparison

Study	The EV Project Participants	California Plug-in Electric Vehicle Owner Survey	This study
Study Population	U.S. PEV owners	CA PEV owners	U.S. PEV owners
Percent Male	63%	71%	77%
Mean Annual Household Income	$149k	$140k	$128k
Mean Education (yrs)	16.9	17.3	17.2
Mean Participant Age (yrs)	50.9	-	52
Percent Have Residential Solar System	-	39%	23%
General Population Have Residential Solar System	-	CA: 0.77%	U.S.: 0.15%

The PEV usage reported shows a broad range of daily vehicle usage, largely staying conservatively within the per-charge battery range limits of today's mass market PEV's, Figure 4. The bulk of participants average 10 – 60 miles per day. Interestingly, 76% of participants average zero charge events per month at commercial pay-per-use EVSE, with 23% using commercial EVSE 1 to 10 times per month, as shown in Figure 4. Half the commercial EVSE usage comes from the top 2% of the most frequent users. The far majority of the commercial EVSE usage is at AC Level 2 EVSE, with only 4% of participants using DCFCs and no participants averaging more than one DC fast charge per month. We also saw low EVSE usage rates in the EV Project quarterly report data presented earlier. Commercial EVSE usage is expected to increase as PEVs become more prevalent.

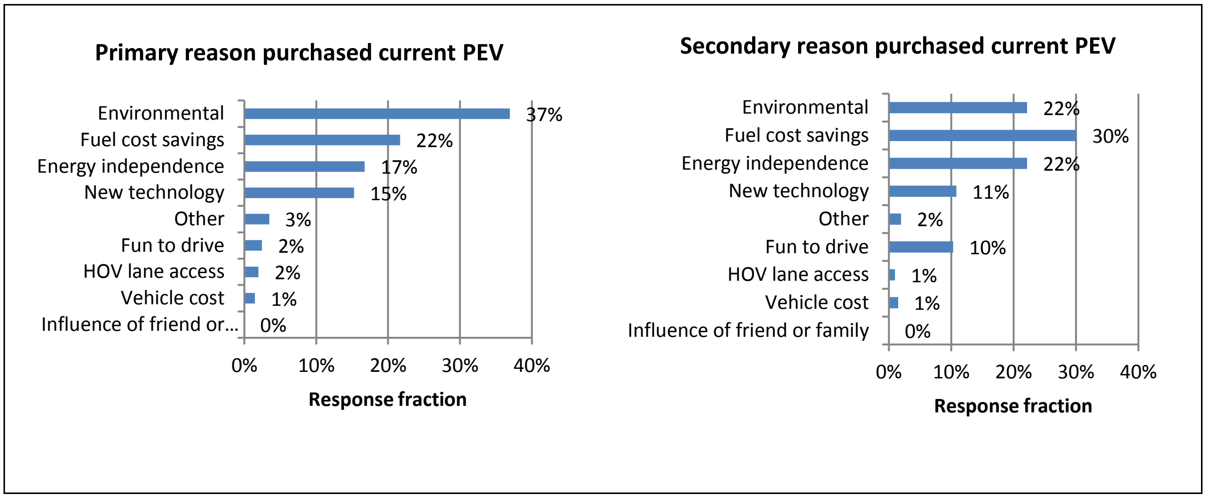

Figure 3. Reason for Purchase of Current PEV

The survey examined direct ask WTP, usage and likelihood for two methods of offering renewably generated electricity. These methods include every charge being renewable and providing an option to upgrade to renewable energy. Figure 5 illustrates the likelihood that the participant would choose an EVSE offering renewable energy over one that does not, with 0% representing indifference and 100% indicating choosing the renewably offering EVSE every time. These two cases are very similar with a slight shift toward increased likelihood for EVSE offering renewable energy as an option. For this case, there is a bimodal distribution, possibly due to differing levels of interest in renewable energy and price sensitivity, with 68% of surveyees indicated a 100% likelihood, 20% indicated a 60% to 99% likelihood and 11% indicated a 0% to 19% likelihood.

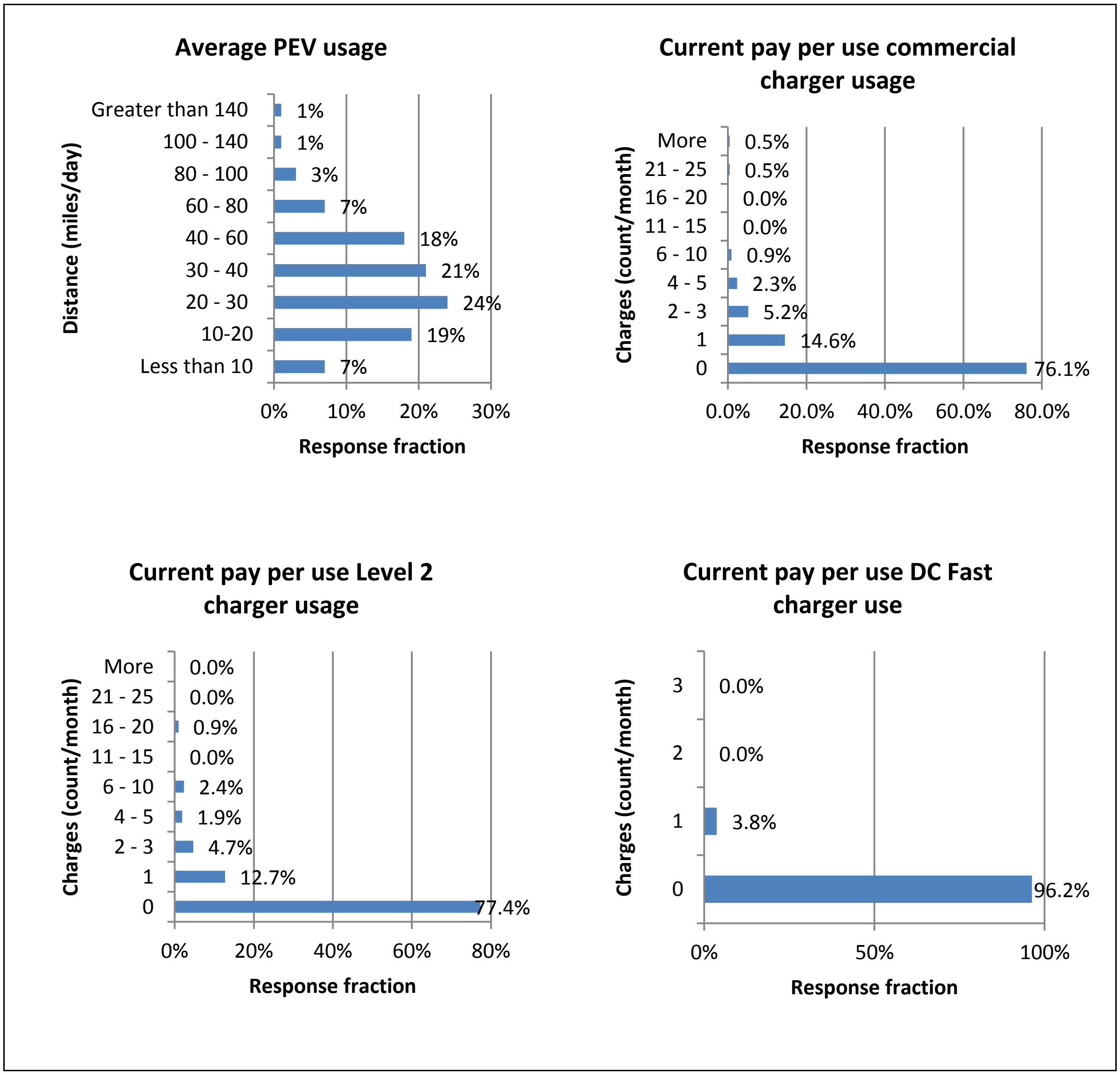

Figure 4. Current PEV and Pay-Per-Use Charger Usage

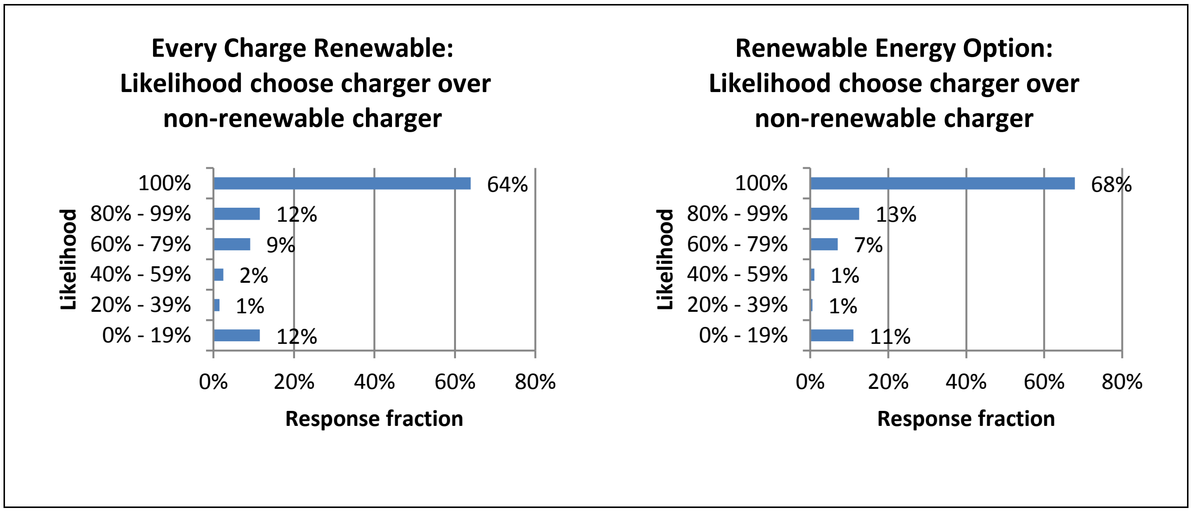

Figure 5. Likelihood of Choosing a Charger Offering Renewable Energy Over Non-Renewable. 0% indicates indifference. 100% indicates choosing renewable offering charger every time.

Comparing current commercial EVSE usage, to stated usage if renewable energy was offered, there is a 497% to 514% increase in monthly charging events when summing usage across all surveyees, representing a mean increase of 3.8 to 3.9 charge events per month per participant, as shown in Figure 6. There is a slightly higher usage indicated for the case of every charge being renewable than for the case of an optional renewable upgrade. As a whole, surveyees indicated that for 99.6% of the charge events, they would choose to use the renewable energy option.

WTP was assessed for AC Level 2 and DCFCs using choice experiment and direct ask methods. At $0.61 per hour to upgrade to 100% renewable energy using AC Level 2 EVSE, the mean WTP collected through the choice experiment method are substantially higher than those from the direct ask method, as shown in Table 4. In the calculation of the direct ask mean WTP and the 95% confidence interval, a value of $0.35 was used for those that selected “more than $0.30,” assuming an additional increment of $0.05. The direct ask 95% interval was calculated using the bootstrap method. As discussed, the choice experiment results are less prone to bias and are expected to be a closer approximation to actual WTP.

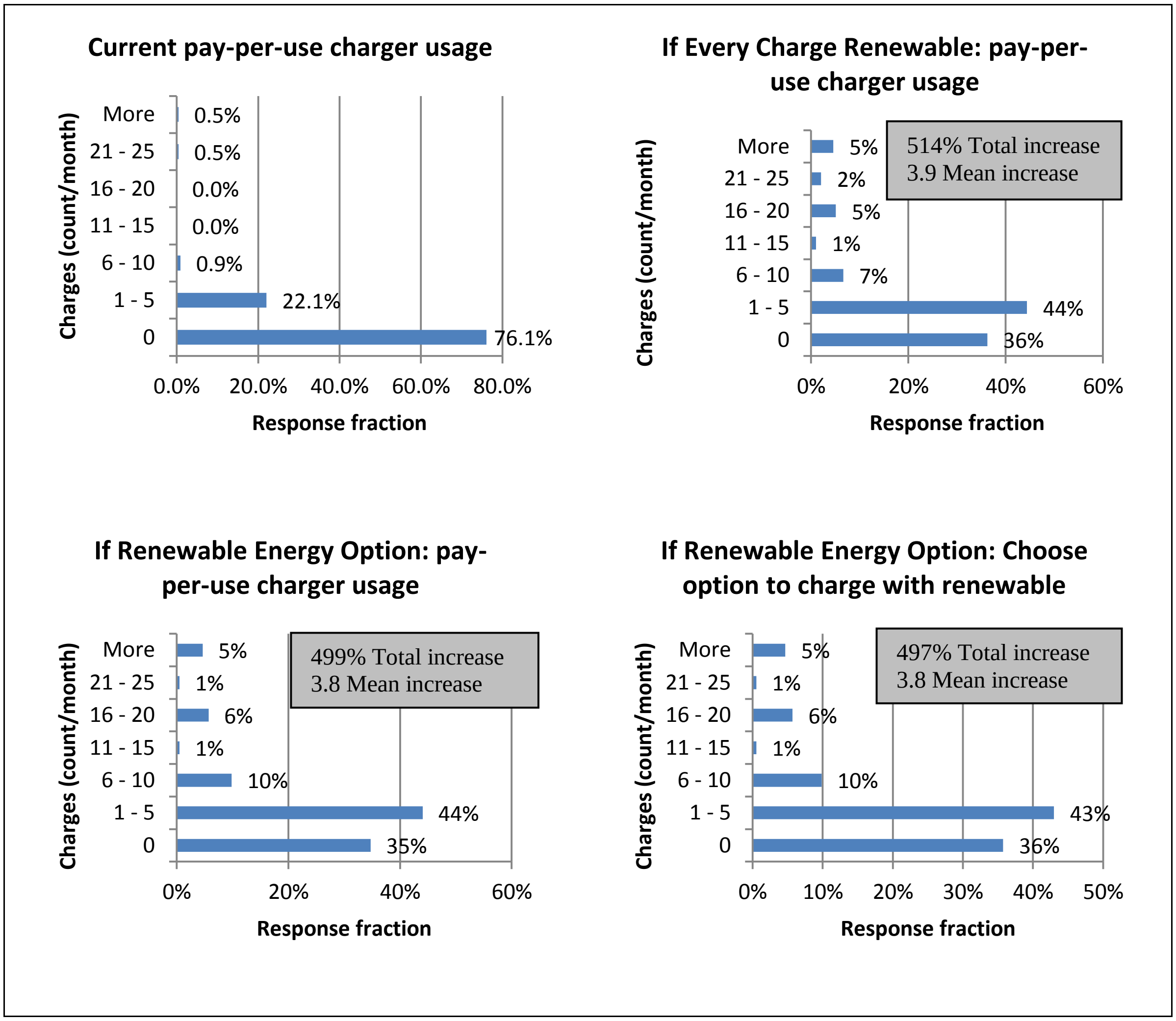

Figure 6. Influence of Renewable Energy Offering on Charger Usage. Total increase is the increase from the sum of current charger usage across all surveyees. Mean increase is the mean increase in charge events per month per surveyee.

The findings for the choice experiment method are based on results from the entire group and do not provide WTP of each surveyee. The distribution of the direct ask AC Level 2 WTP results show little difference between renewable energy being provided with every charge and with it being offered as an option, as shown in Figure 7. There is a slight shift toward higher WTP for the renewable energy option case, which is also apparent in the mean values. For the every charge case, 16% indicate a $0.00 WTP, with the other 84% of surveyees showing interest increasing with increasing WTP and "more than $0.30" being the most selected at 28%.

Trends similar to those seen for AC Level 2 WTP are also apparent for the DCFC, with a mean choice model renewable energy WTP of $1.82 per 30 minute charge, as shown in Figure 8 and Table 5. In the direct ask mean and 95% confidence interval calculation, a value of $1.00 was used in place of "more than $0.80," an additional increment of $0.20. The majority of participants prefer that the EVSE offer renewable energy with every charge, as shown in Figure 9.

Table 4. AC Level 2 Renewable Energy Upgrade WTP Statistics

Survey Method	Mean WTP ($/hr)	95% confidence interval lower bound ($/hr)	95% confidence interval upper bound ($/hr)
Direct Ask – Every Charge	$0.20	$0.19	$0.23
Direct Ask - Optional	$0.21	$0.19	$0.23
Choice Model	$0.61	$0.51	$0.70

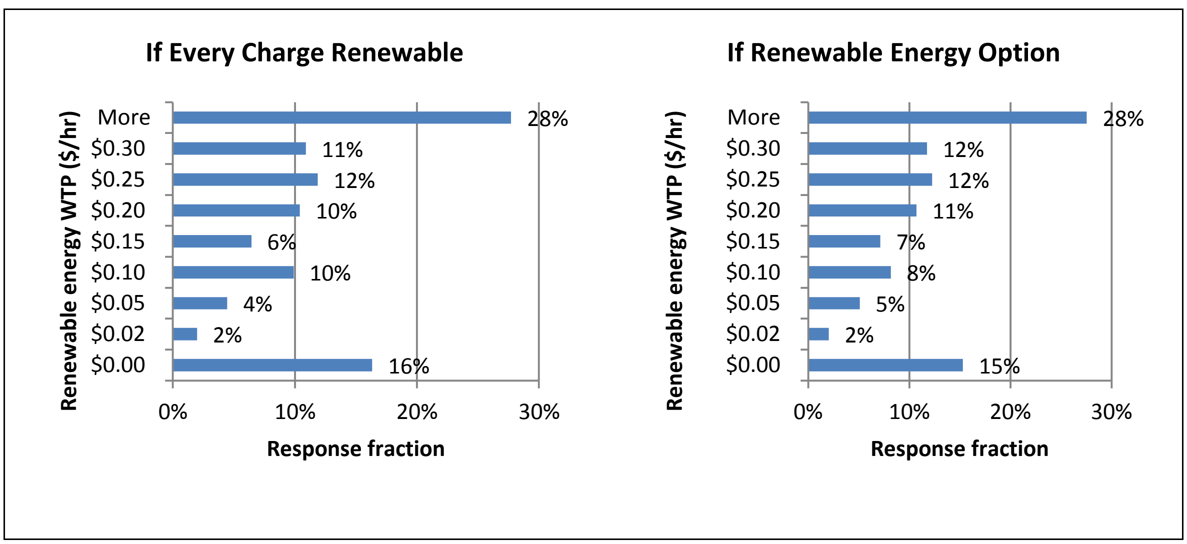

Figure 7. Direct Ask WTP for Renewable Energy on a Commercial Level 2 EVSE

Table 5. 30 Minute DCFC Renewable Energy Upgrade WTP Statistics

Survey Method	Mean WTP ($/charge)	95% interval lower bound ($/charge)	95% interval upper bound ($/charge)
Direct Ask – Every Charge	$0.54	$0.49	$0.61
Direct Ask - Optional	$0.54	$0.49	$0.61
Choice Model	$1.82	$1.51	$2.14

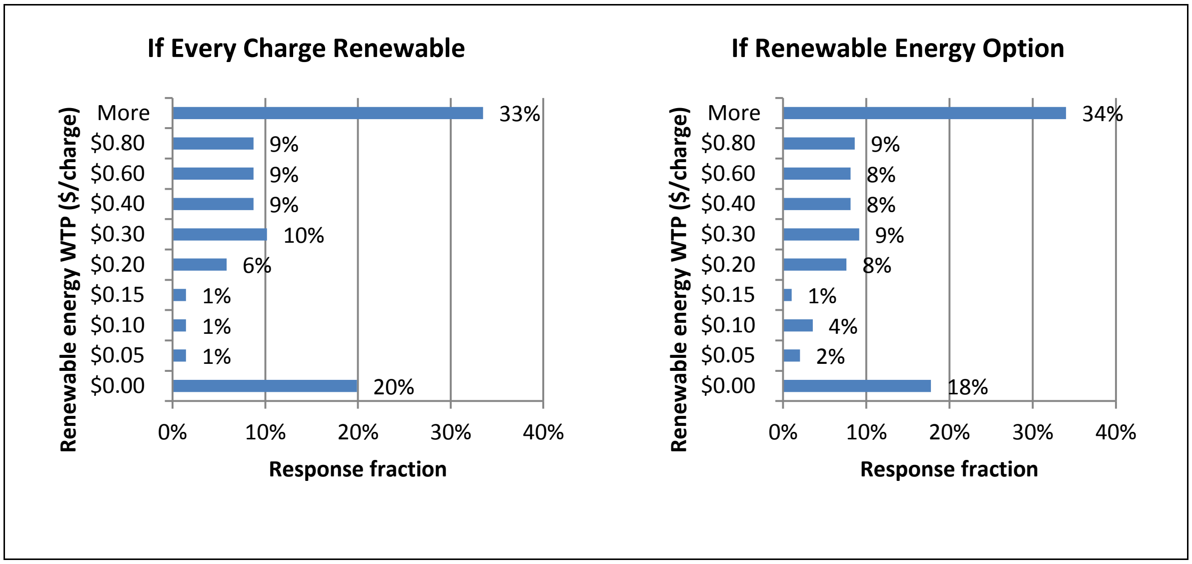

Figure 8. Direct Ask WTP for Renewable Energy on a Commercial DCFC

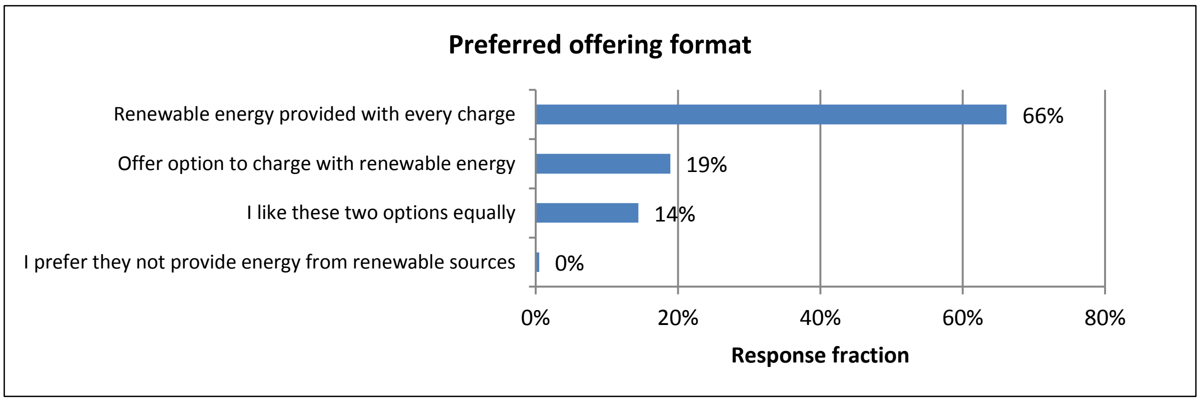

Figure 9. Preferred Renewable Energy Offering Format

Regression Analysis

An ordinary least squares regression was applied to all variations of direct ask WTP, likelihood of choosing a renewable energy offering EVSE and increase in EVSE use from current use as dependent variables. The regression was applied to the results from the 181 surveyees that completed every question. Table 6 shows the dependent variables for which there is a statistically significant regression model based on all the independent variables listed. These models each only explain 6% to 17% of the variability found in the dependent variable. Though, they do provide some trends. The significant correlations with Level 2 renewable energy WTP show

- A $0.06 / hr higher Level 2 WTP for current users of pay-per-use EVSE
- A $0.06 / hr higher Level 2 WTP for those that purchased their PEV for environmental reasons
- A higher WTP for those with higher income

Table 6. Regression Analysis Results. *p<0.1, **p<0.05, ***p<0.01

Dependent Varible	Every Charge: Direct Ask Level 2 WTP		Every Charge: Direct Ask DC Fast WTP		Every Charge: Likelihood choose over non-renewable charger		Optional: Likelihood choose over non-renewable charger		Optional: Charger use increase	
Adjusted R Square	0.154		0.172		0.144		0.168		0.068	
Significance F	0.000		0.000		0.000		0.000		0.033	
Coef	*Mean*	*Std Err*	*Mean*	*Std Err*	*Mean*	*Std Err*	*Mean*	*Std Err*	*Mean*	*Std Err*
Intercept	0.200***	0.069	0.494**	0.211	106.2***	17.953	99.6***	16.970	7.076	9.839
EV vs PHEV (dummy)	0.008	0.020	0.102	0.061	2.000	5.195	2.799	4.910	-0.426	2.847
Miles per day	-0.001	0.000	-0.002	0.001	-0.203*	0.107	-0.182*	0.101	0.055	0.059
Current commercial charge events per month	-0.002	0.004	0.006	0.012	0.100	1.053	0.068	0.995	-0.242	0.577
Current Level 2 charge events per month	-0.004	0.006	-0.008	0.018	-0.271	1.538	-0.511	1.454	-0.102	0.843
Current DC Fast charge events per month	0.028	0.054	0.281	0.166	-6.854	14.102	-14.418	13.330	-3.139	7.729
Currently use commercial chargers (dummy)	0.063***	0.024	0.051	0.073	8.231	6.243	8.068	5.901	-5.483	3.421
Currently have home renewable energy (dummy)	0.003	0.020	0.039	0.060	2.493	5.093	0.107	4.814	4.422	2.791
Environmental reason primary or secondary (dummy)	0.060**	0.026	0.207***	0.079	14.5**	6.735	19.1**	6.366	4.055	3.691
Energy independence reason primary or secondary (dummy)	0.033	0.025	0.058	0.076	-2.522	6.486	-0.617	6.131	4.096	3.555
Fuel cost savings reason primary or secondary (dummy)	-0.023	0.025	-0.091	0.076	-12.3*	6.432	-12.6**	6.080	-1.473	3.525
New technology reason primary or secondary (dummy)	0.016	0.028	0.080	0.085	-16.7**	7.248	-11.207	6.851	0.670	3.972
Number of vehicles household owns	0.009	0.010	0.023	0.030	0.991	2.586	3.256	2.445	-0.769	1.417
Household income (100,000s)	0.393**	0.018	0.174***	0.055	0.3912	4.653	-0.689	4.398	-6.591***	2.550
Education level	-0.007	0.005	-0.040**	0.016	-1.496	1.328	-1.570	1.255	0.065	0.728
Gender	0.018	0.024	0.024	0.072	-3.682	6.122	-3.540	5.787	-2.415	3.355
Age	-0.002	0.001	-0.004	0.003	-0.325	0.224	-0.310	0.212	0.106	0.123

The DC fast charging renewable energy WTP regression indicates:

- $0.21/charge more WTP for those that purchased their PEV for environmental reasons
- More WTP for those with higher incomes
- Less WTP for those with more years of education

For the likelihood of choosing a charger offering renewable over one that does not, there is:

- A weak correlation (with significant at the p = 0.1 level and/or stand error greater than 50% the coefficient mean) of less likelihood with greater daily PEV miles driven
- A weak correlation of lower likelihood for those purchasing their PEV for fuel cost saving reasons.
- A higher likelihood for those purchasing their PEV for environmental reasons

Regression of the indicated increase from current EVSE usage to usage if EVSE offered renewable energy shows that 6% of the variability can be attributed to a trend of a smaller amount of increase in usage for those with higher incomes.

Choice Experiment Results

Several model specifications were fitted in the choice experiment WTP survey mixed logit model, each with the inclusion or exclusion of different independent variables. The results of this analysis are shown in Table 7 for the AC Level 2 EVSE and Table 8 for the DCFCs. In both cases, the following trends emerge:

- Greater WTP for renewable energy for those that use the type of EVSE in question
- WTP increases with an increase in income
- WTP decreases with years of education
- Females are willing to pay more for renewable energy
- WTP increase with age

Table 7. AC Level 2 EVSE Choice Experiment Analysis Results. *p<0.1, **p<0.05, ***p<0.01

***Mean** and Standard Errors of Coefficients*	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Price	-32.358***	-32.273***	-33.056***	-32.448***	-31.865***
	(2.196)	(2.299)	(2.320)	(2.204)	(2.204)
Renewable fraction	19.638***	19.975***	15.786***	20.183***	19.558***
	(1.992)	(2.370)	(5.248)	(2.142)	(2.207)
Renewable fraction * Charge at public commercial charging station (dummy)		5.36***	3.305*		
		(1.404)	(1.884)		
Renewable fraction * Charge at Level 2 commercial charging station (dummy)					5.09***
					(1.273)
Renewable fraction * Income			0.07***		
			(0.015)		
Renewable fraction * Education			-0.416		
			(0.340)		
Renewable fraction * Gender			6.803***		
			(1.871)		
Renewable fraction * Age			0.01		
			(0.056)		
Renewable fraction * Made irrational choices (dummy)				-3.895***	
Standard Error				(1.378)	
***Standard deviations of** the random coefficient*					
Renewable fraction	12.828***	14.719***	13.216***	12.915***	13.647***
	(1.514)	(2.270)	(1.740)	(1.498)	(1.773)
N	6090	6090	5970	6090	6090
LR chi2(2)	1659.6	1617.98	1465.7	1646.49	1610.95
Log likelihood	-702.956	-706.358	-678.779	-702.638	-705.837
*Willingness **to pay estimate***					
Mean	0.606885				
Lower bound for the 95% interval	0.512151				
Upper bound for the 95% interval	0.701618				

Table 8. DCFC Choice Experiment Analysis Results. *p<0.1, **p<0.05, ***p<0.01

	Model 1	Model 2	Model 3	Model 4	Model 5
Price	-14.725***	-14.442***	-14.550***	-14.580***	-14.770***
	(1.128)	(1.104)	(1.130)	(1.129)	(1.129)
Renewable fraction	26.841***	27.586***	39.127***	29.844***	31.620***
	(2.887)	(3.449)	(7.772)	(3.640)	(3.456)
Renewable fraction * Charge at public commercial charging station		8.839***	-3.194***		
		(1.847)	(1.117)		
Renewable fraction * Charge at this type of commercial charging station					42.393***
					(5.685)
Renewable fraction * Income			0.074***		
			(0.021)		
Renewable fraction * Education			-1.386***		
			(0.446)		
Renewable fraction * Female			13.396***		
			(2.138)		
Renewable fraction * Age			0.098**		
			(0.049)		
Renewable fraction * Made irrational choices				7.661***	
				(2.075)	
***Standard deviations of** the random coefficient*					
Renewable fraction	18.426***	20.130***	19.638***	28.791***	24.211***
	(2.347)	(2.800)	(2.426)	(4.296)	(3.057)
N	6090	6090	5970	6090	6090
LR chi2(2)	2357.48	2348.6	2112.12	2344.43	2338.12
Log likelihood	-547.367	-545.731	-529.749	-549.931	-543.379
Willingness ***to pay estimate***					
Mean	1.82283				
Lower bound for the 95% interval	1.507992				
Upper bound for the 95% interval	2.137669				

Case Study: Blink Network

The Blink public EVSE network was built by ECOtality, Inc. as part of The EV Project, which had a total of $230 million in support from the U.S. Department of Energy (DOE), Chevrolet, Nissan and other partners from 2009 to 2013. The EV Project was developed to build a significant charging infrastructure in 18 metropolitan areas across the U.S. and to collect and analyze data needed to learn from the first generation of PEVs to support the development of future vehicles and infrastructure. While this study focuses on the commercial EVSE, the project installed 6,141 residential EVSE in addition to the 2,675 commercial AC Level 2 EVSE and 87 commercial DCFCs (Ecotality North America, 2013). The collected charging data was summarized and published in numerous reports. These publicly available data, specifically the most recent quarterly report of Q2 2013, will be used in this study to calculate potential profitability and environmental benefits. The bankruptcy of ECOtality in September of 2013 led to the purchase of the Blink network by Car Charging Group, Inc.

Profitability

When combined with our survey results, The EV Project quarterly report provides enough information to determine the Blink network Q2 2013 gross income and the increase in gross income and profit, if the offering of renewable energy leads to the usage and mean WTP found in the survey. This information will be annualized by simply multiplying quarterly values by four where appropriate, assuming no seasonal change or other source of increase or decrease in EVSE usage.

AC Level 2 EVSE Price Increase

The information in Table 9 was used to calculate the sought income and profit values for AC Level 2 charging. Since the WTP for renewable energy was surveyed with a base price of $1.00 / hr and since this was the price charged when the 2Q 2013 data were collected and at the time of survey administration, this study uses the pre-September 2014 price.

Table 9.AC Level 2 Renewable Energy Profitability Inputs

Description	Value	Source
Number of charge events	202,916 events / yr	(Ecotality North America, 2013)
Average energy consumption	8.6 AC kWh / event	(Ecotality North America, 2013)
Average time connected	4.5 hr / event	(Ecotality North America, 2013)
Price of charge	$1.00 / hr	(Ecotality North America, 2013)
Wholesale cost of nationally sourced wind energy REC	$0.0012 / AC kWh	(Heeter & Nicholas, 2013)
Mean stated renewable energy WTP	$0.61 / hr	Survey from this study

Gross annual income without renewable energy is calculated by multiplying together the number of charge events per year by the average number of hours per charge event by the price the customer paid for an hour of use.

$$Income_{L2} = 202{,}916\ \frac{events}{yr} \times 4.5\ \frac{hr}{event} \times \$1.00\ /hr = \ \$913{,}122/yr$$

Gross annual income from the sale of renewable energy is calculated similarly though with the mean WTP in place of the base price per hour.

$$Income_{L2,RE} = 202{,}916\ \frac{events}{yr} \times 4.5\ \frac{hr}{event} \times \$0.61/hr\ =\ \$557{,}004/yr$$

This represents a 61% increase in gross income from AC Level 2 charging. The profit without renewable energy cannot be determined as the costs of running the Blink network are not public information. However, the additional profit available through the sale of renewable energy can be calculated using the annual cost of RECs and subtracting this value for the renewable energy gross income.

$$Cost_{L2,RE} = 202{,}916\ \frac{events}{yr} \times 8.6\ \frac{AC\ kWh}{event} \times \$00012/AC\ kWh = \ \$2{,}094/yr$$

$$Profit_{L2,RE} = Income_{L2,RE} - Cost_{L2,RE} = \$554{,}910/yr$$

This value indicates a 99.6% profit on the sale of renewable energy. Nationally sourced wind RECs sold on the voluntary, non-compliance market have traded below $0.002 / kWh since 2010. The highest wind voluntary REC prices to date were observed for wind energy generated in the western U.S. during some price peaks between 2009 and 2012, with values topping out at $0.0086 / kWh. While nationwide sourced wind was available at $0.001 to $0.0015 during this period and there is no reason not to use the lower priced RECs, the effect of this higher price is noted as a point of profit sensitivity.

$$Cost_{L2,RE}\ \times \frac{\$0.0086}{\$0.0012} = \$15{,}007$$

The higher REC cost is clearly still well below $Income_{L2,RE}$, leaving a 97.3% profit, relative to the gross renewable energy income.

DCFCs Price Increase

The needed inputs for the income and profit values from the sale of renewable energy on the DCFCs are presented in Table 10.

Table 10. DCFC Renewable Energy Profitability Inputs

Description	Value	Source
Number of charge events	107,644 events / yr	(Ecotality North America, 2013)
Average energy consumption	8.3 AC kWh / event	(Ecotality North America, 2013)
Price of charge	$5.00 / event	(Ecotality North America, 2013)
Wholesale cost of nationally sourced wind energy REC	$0.0012 / AC kWh	(Heeter & Nicholas, 2013)
Mean stated renewable energy WTP	$1.82 / event	Survey from this study

Following the same process, the DC fast charging gross annual income without renewable energy, the gross annual income from the sale of renewable energy, the cost of RECs and renewable energy profit is calculated as follows.

$$Income_{DC} = 107{,}644\ \frac{events}{yr} \times \$5.00\ /event = \ \$538{,}220/yr$$

$$Income_{DC,RE} = 107{,}644\ \frac{events}{yr} \times \$1.82/hr\ = \ \$195{,}912/yr$$

$$Cost_{DC,RE} = 107{,}644\ \frac{events}{yr} \times 8.3\ \frac{AC\ kWh}{event} \times \$00012/AC\ kWh = \ \$1{,}072/yr$$

$$Profit_{DC,RE} = Income_{DC,RE} - Cost_{DC,RE} = \$194{,}840/yr$$

These values indicate a 36% increase in gross income and 99.4% profit from the sale of renewable energy on DCFCs.

Totaling and Usage Increase

Totaling values from AC Level 2 and DCFC EVSE, the price increase provided by the added value of selling renewable energy with every charge would increase gross annual income by 52% from $1.45 million to $2.20 million and increase annual profits by $0.75 million.

Averaging the stated usage increase from the every charge renewable case and the optional renewable case provides a usage increase of 505.5%. Such a rise would bring the gross annual income increase to 668% from the original $1.45 million to $11.1 million. At this usage rate, the cost of RECs would raise to $16,005, while the profit resulting from the renewable energy price premium would be $3.8 million.

Environmental Benefit

A well-to-wheels life cycle impact assessment comparison of powering vehicles with three different energy sources was conducted using the GREET model produced by Argonne National Laboratory (US Argonne National Laboratory, 2014). Figure 10 compares the energy costs and emissions for a vehicle powered with gasoline, average U.S. grid electricity mix and wind generated electricity, based on U.S. average residential electric utility pricing and U.S. average gasoline cost 9/2013 – 8/2014, (US Energy Information Administration, 2014) (US Energy Information Administration, 2014).

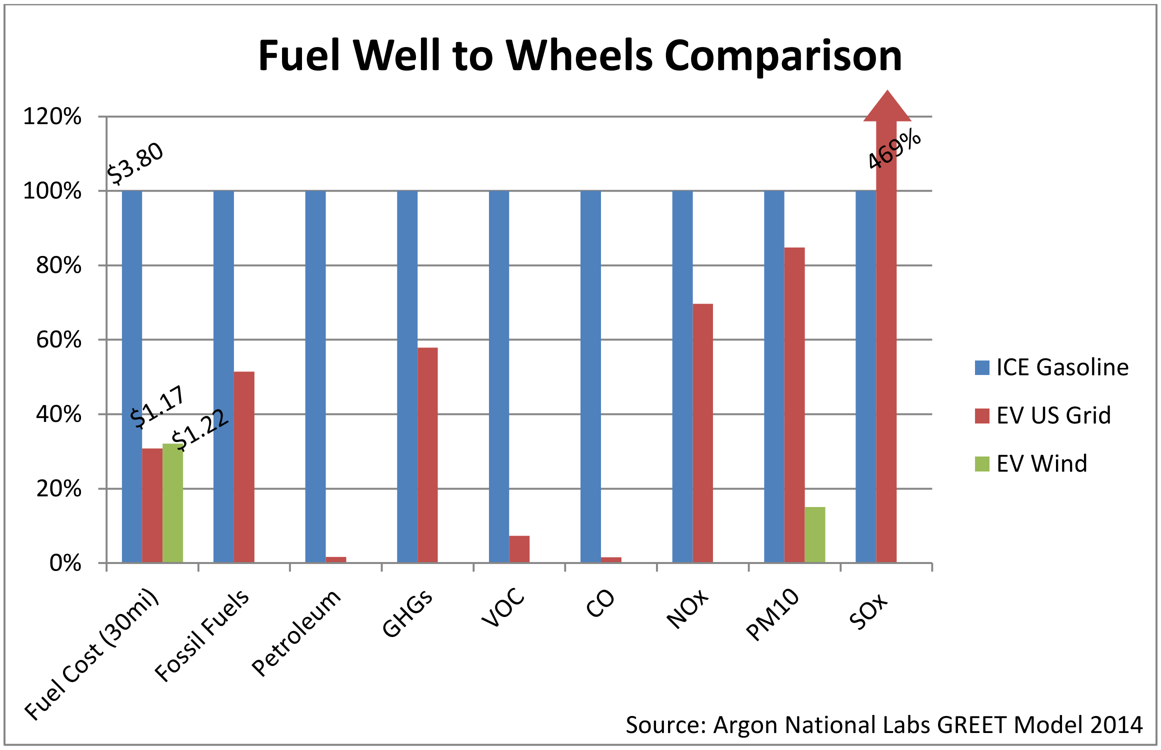

Figure 10. Well-to-Wheels Life Cycle Emissions and Costs

These results show energy costs for 30 miles of travel in a U.S. passenger vehicle at $3.80 for gasoline, $1.17 for residential grid electricity and $1.22 for residential wind energy. Switching from gasoline to average U.S. mix electricity reduces every modeled emission type with the exception of SO_x. Switching from gasoline to wind power reduces emissions of every modeled type by more than 4 orders of magnitude, with the exception of PM10. Relative to gasoline, GHGs are 42% less for grid electricity and 99.997% less for wind energy.

The total annual energy distributed by the Blink network can be calculated by summing the total annualized 2Q 2013 AC Level 2 and DCFC energy consumption as follows, using the values from Table 9 and Table 10.

$$202{,}916\ \frac{events}{yr} \times 8.6\ \frac{AC\ kWh}{event} + 107{,}644\ \frac{events}{yr} \times 8.3\ \frac{AC\ kWh}{event} = 2{,}639\ MWh/yr$$

Using an average U.S. electricity mix carbon dioxide intensity factor (US Environmental Protection Agency, 2014) the total annual grid electricity carbon dioxide emissions for the Blink network are

$$2{,}639\ MWh/yr\ \times 602kg\ CO_2/MWh = \ 1{,}589 \text{ metric tons } CO_2/yr$$

Using the factor of CO_2 emitted by wind energy relative to that for grid energy from the GREET model, powering every charge with wind energy would prevent the emission of

$$1{,}589 \text{ metric tons } CO_2\ \times 7.91 \times 10^{-5} = \ 125\ kg\ CO_2/yr$$

This equates to the prevention of 1,589 metric tons CO_2 per year or the removal of 334 U.S. passenger cars from the road (US Environmental Protection Agency, 2014). At the increased survey stated usage rate, these figures increase to 8,031 metric tons CO_2 prevented per year and the elimination of 1,691 passenger cars.

CHAPTER 5

CONCLUSIONS

Previous studies and the survey findings of this study show PEV drivers have a higher-than-average interest in renewable energy and in protecting the environment, with currently 50% powering their home with renewable energy and 60% having purchasing their PEV for environmental reasons. Both these finding are demonstrations of a will to take action and pay for reducing their environmental impact. The survey results indicate a 505% increase in the usage of the EVSE if renewable energy was offered and a mean WTP to upgrade to renewable energy of $0.61 per hour for AC Level 2 EVSE and $1.82 for DCFCs. Based on data from the 2013 second quarter report of The EV Project, this usage translates directly to an annual gross income increase of 668% from the original $1.45 million to $11.1 million. Blink would pay a cost of $16,005 to purchase RECs. Excluding any profit seen purely from the raise in usage, $3.8 million in profits would be gained directly from the renewable energy price premium.

Looking at residential and retail energy pricing, the cost for 30 miles of travel in a U.S. passenger vehicle is $3.80 for gasoline, $1.17 for residential grid electricity and $1.22 for residential wind energy. Switching from gasoline to wind power reduces emissions of GHGs, VOCs, CO, NO_x, and SO_x by more than 4 orders of magnitude. Relative to gasoline, GHGs are 42% less for U.S. average blend grid electricity and 99.997% less for wind energy. Powering all Blink network charge events with wind energy would reduce the annualized 2Q 2013 GHG emissions of 1,589 metric tons CO_2/yr to 125 kg CO_2/yr the equivalent of removing 334 U.S. gasoline passenger cars from the road. At the 505% survey stated increased usage, 8,031 metric tons CO_2/yr would be prevented per year or the equivalent of the elimination of 1,691 passenger cars. These economic and environmental benefit values will increase with the usage of commercial chargers, which is expected to increase as PEV ownership increases with time. Customer trials with actual purchases would better refine these economic and environment benefit values.

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APPENDIX A

SURVEY

Research Investigators: Dr. Yueming Lucy Qiu, Assistant Professor (yueming.qiu@asu.edu) Ian Nienhueser, Graduate Student, (Ian.Nienhueser@asu.edu) Information for Survey Participants This study is being conducted by researchers from Arizona State University. The purpose is to determine if people are interested in powering electric vehicles with renewable energy. We are inviting your participation, which will involve completing a 10 minute survey. You have the right to stop participation at any time. Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. The summarized results of the survey responses will be published in scientific literature. There are no foreseeable risks or discomforts to your participation. We will insure your confidentiality by not collecting your name or any personally identifiable information. Your responses will be anonymous. The results of this study may be used in reports, presentations, or publications but your name will not be used. Results will only be shared in the aggregate form. If you have any questions concerning the research study, please contact the research team at: (480-727-4097, Dr. Qiu). If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

For each combination in the following, there are two options of charging your electric vehicle at a Level 2 commercial charging station. The two options differ in: 1) Percentage of electricity coming from renewable sources such as wind or solar at this charging station 2) Price of charging per hour There are 10 combinations in total. For each combination, please choose your preferred alternative of charging or choose "Neither of these".

- ❍ 50% Renewable energy $1 per hour
- ❍ 50% Renewable energy $1.06 per hour
- ❍ Neither of these

- ❍ 75% Renewable energy $1.06 per hour
- ❍ 0% Renewable energy $1 per hour
- ❍ Neither of these

- ❍ 50% Renewable energy $1.18 per hour
- ❍ 50% Renewable energy $1.24 per hour
- ❍ Neither of these

- 100% Renewable energy $1.24 per hour
- 25% Renewable energy $1.12 per hour
- Neither of these

- 100% Renewable energy $1.18 per hour
- 25% Renewable energy $1.06 per hour
- Neither of these

- 25% Renewable energy $1.06 per hour
- 75% Renewable energy $1.18 per hour
- Neither of these

- 0% Renewable energy $1.12 per hour
- 100% Renewable energy $1.18 per hour
- Neither of these

- 25% Renewable energy $1 per hour
- 75% Renewable energy $1 per hour
- Neither of these

- 0% Renewable energy $1.12 per hour
- 100% Renewable energy $1.24 per hour
- Neither of these

- 75% Renewable Energy $1.24 per hour
- 0% Renewable Energy $1.12 per hour
- Neither of these

For each combination in the following, there are two options of charging your electric vehicle at a 30 Minute DC Fast commercial charging station. The two options differ in: 1) Percentage of electricity coming from renewable sources such as wind or solar at this charging station 2) Price of charging per charge. There are 10 combinations in total. For each combination, please choose your preferred alternative of charging or choose “Neither of these“.

- ❍ 50% Renewable Energy $5 per charge
- ❍ 50% Renewable Energy $5.15 per charge
- ❍ Neither of these

- ❍ 75% Renewable Energy $5.15 per charge
- ❍ 0% Renewable Energy $5 per charge
- ❍ Neither of these

- ❍ 50% Renewable Energy $5.45 per charge
- ❍ 50% Renewable Energy $5.60 per charge
- ❍ Neither of these

- ❍ 100% Renewable Energy $5.60 per charge
- ❍ 25% Renewable Energy $5.30 per charge
- ❍ Neither of these

- ❍ 100% Renewable Energy $5.45 per charge
- ❍ 25% Renewable Energy $5.15 per charge
- ❍ Neither of these

- ❍ 25% Renewable Energy $5.15 per charge
- ❍ 75% Renewable Energy $5.45 per charge
- ❍ Neither of these

- 0% Renewable Energy $5.30 per charge
- 100% Renewable Energy $5.45 per charge
- Neither of these

- 25% Renewable Energy $5 per charge
- 75% Renewable Energy $5 per charge
- Neither of these

- 0% Renewable Energy $5.30 per charge
- 100% Renewable Energy $5.60 per charge
- Neither of these

- 75% Renewable Energy $5.60 per charge
- 0% Renewable Energy $5.30 per charge
- Neither of these

Now, we would like to ask you some additional questions.

Do you own or lease an electric vehicle?

- No
- Yes, a plug-in hybrid
- Yes, an all-electric vehicle

On average how many miles do you drive your electric vehicle per day?

- Less than 10 miles
- 10 - 20 miles
- 20 - 30 miles
- 30 - 40 miles
- 40 - 60 miles
- 60 - 80 miles
- 80 - 100 miles
- 100 - 140 miles
- Greater than 140 miles

How many times per month do you charge your vehicle on a pay per use commercial charger?

How many times per month do you charge your vehicle on a pay per use a Level 2 charger?

How many times per month do you charge your vehicle on a pay per use a 30 Minute DC Fast charger?

If 100% renewable energy such as wind or solar was provided by commercial charger with every charge:

How much more likely would you choose this charger over one that does not provide renewable energy? 0% meaning it would not influence your decision.100% meaning you would use the renewably powered charger every time

How many times per month would you charge on a commercial charger, if they provided renewable energy with every charge?

How much extra would you be willing to pay to use a renewably powered 30 Minute DC Fast charger, per charge?

- $0.00 per charge
- $0.05 per charge
- $0.10 per charge
- $0.15 per charge
- $0.20 per charge
- $0.30 per charge
- $0.40 per charge
- $0.60 per charge
- $0.80 per charge
- More than $0.80 per charge

How much extra would you be willing to pay to use a renewably powered Level 2 charger, per hour?

- $0.00 per hour
- $0.02 per hour
- $0.05 per hour
- $0.10 per hour
- $0.15per hour
- $0.20per hour
- $0.25 per hour
- $0.30 per hour
- More than $0.30 per hour

If the commercial charger provided as an option 100% renewable energy such as wind or solar:

How much more likely would you choose this charger over one that does not provide renewable energy? 0% meaning it would not influence your decision.100% meaning you would use the renewably powered charger every time

How many times per month would you charge on this charger that offers the option of renewable energy?

How many times per month would you choose to use the option to charge with renewable energy on this charger?

How much extra would you be willing to pay to use the option to charge with renewable energy on a 30 Minute DC Fast charger, per charge?

- $0.00 per charge
- $0.05 per charge
- $0.10 per charge
- $0.15 per charge
- $0.20 per charge
- $0.30 per charge
- $0.40 per charge
- $0.60 per charge
- $0.80 per charge
- More than $0.80 per charge

How much extra would you be willing to pay to use the option to charge with renewable energy on a Level 2 charger, per hour?

- $0.00 per hour
- $0.02 per hour
- $0.05 per hour
- $0.10 per hour
- $0.15 per hour
- $0.20 per hour
- $0.25 per hour
- $0.30 per hour
- More than $0.30 per hour

Would you prefer for the commercial chargers to provide renewable energy with every charge or that they offer an option to charge with renewable energy?

- ❍ Renewable energy provided with every charge
- ❍ Offer option to charge with renewable energy
- ❍ I like these two options equally
- ❍ I prefer they not provide energy from renewable sources

If a charger host, such as a store, restaurant, mall, etc. provided a free upgrade to renewable energy for the charger at their site, how much more frequently would you patron that business?

- ❍ 0% more
- ❍ 10% more
- ❍ 25% more
- ❍ 50% more
- ❍ Twice as often
- ❍ Four times as often
- ❍ More than four times as often

When you replace your electric vehicle, how likely is it that you will replace it with another electric vehicle? 0% meaning you will absolutely not replace it with an electric vehicle. 100% meaning you will absolutely replace it with an electric vehicle.

If commercial chargers provided renewable energy such as wind or solar, when you replace your electric vehicle, how likely is it that you will replace it with another electric vehicle? 0% meaning you will absolutely not replace it with an electric vehicle. 100% meaning you will absolutely replace it with an electric vehicle.

Do you currently charge your vehicle at home with renewable energy such as wind or solar?

- ❍ Yes, with onsite solar or wind
- ❍ Yes, through my electric utility
- ❍ No
- ❍ Other ____________________

To charge at home with renewable energy such as wind or solar, how much do you or would you be willing to pay per month in addition to your preexisting electric bill?

- ❍ $0.00 per month
- ❍ $1.00 per month
- ❍ $2.00 per month
- ❍ $4.00 per month
- ❍ $6.00 per month
- ❍ $8.00 per month
- ❍ $10.00 per month
- ❍ more than $10.00 per month

If you could charge at home with renewable energy such as wind or solar, when you replace your electric vehicle, how likely is it that you will replace it with another electric vehicle? 0% meaning you will absolutely not replace it with an electric vehicle. 100% meaning you will absolutely replace it with an electric vehicle.

What is the primary reason you purchased your current electric vehicle?

- ❍ Fuel cost savings
- ❍ Vehicle cost
- ❍ Environmental
- ❍ Energy independence
- ❍ New technology
- ❍ Fun to drive
- ❍ HOV lane access
- ❍ Influence of friend or family
- ❍ Other ____________________

What is the second greatest reason you purchased your current electric vehicle?

- ❍ Fuel cost savings
- ❍ Vehicle cost
- ❍ Environmental
- ❍ Energy independence
- ❍ New technology
- ❍ Fun to drive
- ❍ HOV lane access
- ❍ Influence of friend or family
- ❍ Other ____________________

How many vehicles does your household own?

What is your annual household income?

- ❍ Less than $30,000
- ❍ $30,000 - $50,000
- ❍ $50,000 - $70,000
- ❍ $70,000 - $100,000
- ❍ $100,000 - $150,000
- ❍ more than $150,000

What is your highest education level?

- ❍ High school diploma
- ❍ Some college
- ❍ Technical school diploma
- ❍ Bachelor's degree
- ❍ Master's Degree
- ❍ Doctorate
- ❍ Other ____________________

What is your age?

What is your gender?

- ❍ Male
- ❍ Female

IMPORTANT: You MUST click on the next button below in order for your answer to be submitted to the system. Thank you for your cooperation. If you have any further suggestions or comments, please enter them here.