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ECONOMIC ASSESSMENT OF ELECTRIC-DRIVE VEHICLE OPERATION IN CALIFORNIA AND THE UNITED STATES

ABSTRACT

This study examines the relative economics of electric vehicle operation in the context of current electricity rates in specific utility service territories. The authors examined 14 utility territories offering electric vehicle (EV) rates, focusing on California but also including other regions of the United States. The consumer costs of EV charging were examined in comparison with gasoline price data, geographic location, and during three highly variable gasoline price periods of July 2008, January 2009, and July 2009. In a switch from a conventional 23 mile per gallon (10.2 liters/100 kilometers) vehicle to a 300 watt-hours/mile electric vehicle driven 10,000 miles (16,100 km) per year, the study finds that savings in fuel costs ranged from approximately $100US to $1,800US annually, with considerable geographic variation and with higher-end values mostly in Summer 2008 when gasoline prices were relatively high. Charging off-peak instead of during peak periods saves an average of only a few hundred dollars US per year, rendering the incentive to charge off-peak a relatively small one except perhaps during some summer months when the on-peak prices are especially high. Gasoline price variances have a larger effect and switching from a low fuel economy conventional vehicle to the reference EV (compared with a switch from an already efficient vehicle) presents the highest savings level. The West and Midwest are generally the most favorable regions for EV economics, when EV charging rates and gasoline prices are considered together.

Key Words: electric vehicle, electricity utility, time-of-day rate, plug-in hybrid, operational cost

INTRODUCTION

This study examines the extent to which specific utility EV electricity rates, in combination with fluctuating local gasoline prices, can be shown to provide vehicle operational economic benefits of switching from conventional to electric vehicles (EVs). The context for the study is the resurging interest in EVs, including plug-in hybrid electric vehicles (PHEVs) and pure battery electric vehicles (BEVs). Several established and new-entry automakers have now announced their intent to commercialize these vehicles in the 2010 to 2012 timeframe and in a few cases have already done so.

The main goal of this study is to gain consumer market and policy insights related to the latest electricity rates in California and across the United States (U.S.) that have been developed for EV recharging. At present, there are significant other purchase incentives for consumers to switch to electric-drive vehicles, including a major federal program that would save consumers up to $7,500US per “new qualified plug-in electric drive vehicle” through a tax credit that runs through the end of 2014 (*1*). There also are various state-level programs such as the California Fueling Alternatives Rebate Program whose first phase just ended, which offered up to $5,000US for qualified electric and other alternative fuel vehicles for a few years (*2*). These programs were put in place to help to encourage the early commercialization of EVs for their environmental and energy-use benefits, but they are not expected to last in the longer term when relative EV costs to consumers are expected to have declined.

Previous studies of the overall economics of PHEVs have found that reducing the cost of PHEV batteries is critical to their ability to achieve cost-effective greenhouse gas (GHG) reductions compared with other strategies. There also are important trade-offs related to vehicle design, where larger capacity battery PHEVs will have more expensive battery packs in an absolute sense but lower costs per kilowatt-hour (kWh) when expressed in those terms (*3*). With regard to cost effectiveness in reducing GHGs, one study found that with current battery prices, PHEVs require very low-carbon electricity to be cost effective or significant government subsidies to lower consumer costs (*4*). The study found that battery costs below about $500US per kWh can lead to reasonably cost-effective PHEVs for GHG abatement, depending on the carbon intensity of the electricity generation and the value of the carbon reduction per ton. The study further found that if PHEV battery costs could reach $200US per kWh, then PHEVs could be cost effective for consumers and society even absent the consideration of GHG benefits and the generation method (*4*).

Another key issue is the EV design, particularly for PHEVs where vehicles can be designed as either “series drive/charge depleting” or “power split/blended mode” hybrids and with varying amounts of battery capacity in each case. The distinction between series drive and blended mode relates to the extent to which the vehicle can purely rely on the electric drive system for propulsion. Series drive hybrids only use the electric motor for direct propulsion, where the gasoline engine runs a generator to recharge the battery, while blended mode hybrids use the electric drive to supplement what is typically a larger gasoline engine propulsion system and where both are connected to the vehicle transmission in a more conventional hybrid vehicle configuration. Charge-depleting hybrids offer the ability to completely shut the gasoline engine off for significant time periods, especially at high states of battery charge, thus running in “pure EV mode.” The amount of battery capacity included in a PHEV is often referred to in terms of how many miles of all-electric range (AER) is available, which is a theoretical concept for blended-mode hybrids (e.g., “PHEV-20” for a PHEV with 20 miles/32 kilometers (km) of AER and “PHEV-40” for 40 miles/64 km of AER).

With regard to EV fuel costs, many electric utilities offer attractive electricity rates or off-peak charging at nighttime hours, with what are called “time-of-use” (TOU) rates. EV owners who install a separate meter for their vehicle can qualify for better rates, offering considerable savings over the rates that often would apply if the EV charging was billed through the regular household meter and the regular residential rate tariff. This is because many utilities have reverse-tiered billing, where the power cost to residential consumers goes up in steps with higher monthly usage rates. Other incentives for EVs and alternative-fuel vehicles are based on other aspects of vehicle ownership, such as in California where very clean fuel vehicle drivers can get carpool lane stickers.

Thus, some major utility companies offer special EV rates, which may or may not include TOU rates. This paper investigates the annual savings gained or lost by drivers who make use of special EV rates or the time-of-day rates where available, the variation in the rates around the country, and the extent to which these variable rates help or hurt the private economics of EV ownership. As much of the electricity supply is unused during off-peak hours (*5, 6*), providing incentives for EV charging during these times could help the economics of utility companies by making better and more efficient use of the utility grid through higher realized capacity factors, reducing the overall costs of delivering power to consumers.

This paper examines in detail variations in EV operating costs around California and the U.S., focusing on differences in electricity and gasoline fuel expenses and especially analyzing the latest utility electricity rate schedules in detail. As some of the utility TOU rate schedules are rather complex, involving TOU, weekly, and seasonal characteristics as well as a tiered structure (where rates go up in tiers by the amount used per month), the authors developed a detailed spreadsheet analysis tool to calculate annual fuel costs for electricity and savings compared with gasoline costs. Following the methodological discussion and study results, the authors examine notable policy implications in the results section and provide a summary conclusion.

METHODOLOGY

This section describes the data collected, the assumptions used, and the analysis approach. The dataset of utility EV charging rates does not represent a random sample but more a representation of large population regions where residential EV electricity rates may be available. Thus, the results are illustrative of what EV drivers in California and different parts of the country may expect, but they are only comprehensive in California.

Electric Utility Rate and Gasoline Price Data

Rates from utility companies found to offer special EV charging rates or TOU pricing options were collected for May 2009. Some companies represented a whole state or many states, while others only covered a metropolitan area within a state. Further, some companies had multiple sub-companies where each may have their own rates or sub-regions within their jurisdiction with varying rates. Parent utility company service territories numbered 14, with sub-companies, sub-regions, and service differences providing 42 final rate structures (see Table 1). Peak and off-peak rates were offered by 20 (49%) of the utilities. An additional medium-peak rate was offered by 11 (27%) additional utilities. Only four (10%) of the utilities had a flat rate scheme, while six (15%) offered a tiered rate scheme (based on use, not time-of-day). One utility has peak and off-peak rates and a tiered scheme with increasing usage (Pacific Gas & Electric Company in Northern California).

Statewide and metropolitan area average prices for regular octane gasoline were obtained from the American Automobile Association (AAA) (*7*). An examination of additional regional gasoline price using federal Energy Information Administration data confirms that both low and high national prices are reflected in this study by virtue of the inclusion of Texas and Colorado for some of the lowest prices in the country and California and Hawaii for the highest prices (*8*).

Additional Assumptions and Underlying Analysis

Most utility companies have electric rates that varied by season of the year. Driving patterns can also vary somewhat seasonally, but for purposes of this analysis the authors did not assume seasonal variations in driving distances.

Also, while outdoor temperatures often require heating or cooling within a vehicle, the base case analyzed here assumes that EV energy use is constant, with an overall average of 300 watt-hours (Wh) per mile/km from the wall plug (whether a battery EV or a PHEV for either actual or theoretical "AER miles"). This value typically ranges from about 200 Wh/mi (124Wh/km) for small electric vehicles up to 400 Wh/mile (249Wh/km) for larger vehicles and also depends on vehicle design. For example, for the extensively tested Toyota RAV4 "small SUV" type of EV, using its test mileage for U.S. Environmental Protection Agency (EPA) certification purposes and the "55/45" city/highway mileage split yields 301 Wh/mi (187 Wh/km), based on the reported 270 Wh/mi (168 Wh/km) city and 340 Wh/mi (211 Wh/km) highway (*9*).

More modern EVs coming on the market in 2010 from Nissan and Mitsubishi, as well as PHEVs from Toyota, GM, Ford, and other manufacturers in the 2010 to 2012 timeframe are likely to exhibit higher energy efficiency than the now several years old RAV4 EV from Toyota due to battery and other recent improvements. Hence, an assumption of 300 Wh/mi or 190 Wh/km—either actual in a charge-depleting hybrid or "virtual" for a blended mode hybrid—for a near-term EV sedan or small SUV is reasonably conservative for this analysis, but it is also intended to account for charging losses to be a value of electricity used from the wall plug. More efficient EVs will exhibit more savings than this paper presents.

With regard to a comparison of conventional vehicle fuel economy, an analysis of the federal Bureau of Transportation Statistics national averages for U.S. passenger vehicles (cars and light trucks) currently in use produced an estimate of 23 miles per gallon (mpg) (or 10.2 liters/100 km) *(10)*. The authors note that over time this number will increase due to recent regulations requiring fleet averages of 35 mpg (6.7 liters/100km) by 2020. Hence, further looking studies of EVs relative to conventional vehicles will have to consider this changing landscape of vehicle fuel economy in their consideration of EV operational economics relative to conventional vehicles. Of course, as with EV energy use, this assumption can be easily varied to examine more specific cases.

The estimated savings per year is further based on traveling an assumed 10,000 electric miles (16,100 km) per year. This number implies either a pure BEV or a PHEV with significant AER of at least 40 miles (64 km) and somewhat higher overall miles (km) driven than 10,000 (16,100) for PHEV drivers. One recent study of the interaction between PHEV design and driving patterns suggests that about 50% of drivers drive less than 40 miles (64 km) per day on average, and 70 to 80% of drivers drive less than 50 miles (80 km) (*11)*. This means that the 10,000 miles (16,100 km per year) of "electric mile" driving assumed in this study could be captured either by a BEV driver driving 10,000 miles (16,100 km) per year, a PHEV-40 driver driving approximately 20,000 miles (32,200 km) per year, or supplementing off-peak charging with some peak charging (*12*). Many PHEV-40 or PHEV-50 drivers who did some morning recharging at their work location could easily capture 80 to 90% of their total driving with electric fuel. This may or may not be the most economical overall vehicle solution due to higher battery costs for PHEV-40 and PHEV-50 vehicles compared with PHEV-10 or PHEV-20 vehicles, but it does allow for higher operational cost savings in terms of electricity versus gasoline.

For comparison purposes, annual fuel-cost savings are estimated for 100% off-peak charging, 100% peak charging, and each increment of 10% in between. A linear combination of the off-peak and peak rates was used for the incremental estimates. Some electric utilities had off-peak, medium-peak, and peak rates. For those companies, the medium-peak rate was ignored. Future analysis based on more detailed assessment of driving and charging patterns would allow for these rate periods to be considered more carefully in scenarios of vehicle use for specific drivers; again, the current study is meant to be illustrative of the variation in electricity charging costs by the amount of charging done off-peak.

Costs of traveling 10,000 miles (16,100 km) were calculated for both an EV and a replaced gasoline vehicle that averaged 23 mpg (10.2 liters/100km). For purposes of this comparison, an average gasoline price was used to represent an example year. The savings is the difference between the two costs and is based only on energy consumption. Additional savings from lack of smog tests, oil changes, higher maintenance costs associated with combustion engines and environmental or GHG emission savings were not included. To gain further policy insights, sensitivity analyses were conducted for the gasoline price and the average fuel economy of the comparison vehicle.

Data processing and analysis was done in Microsoft Excel 2004 and 2008 (Seattle, WA), with the three-dimensional plots rendered in MatLab version r2006b by The MathWorks, Inc. (Natick, MA).

RESULTS

The annual operational savings figures for the three gasoline price periods analyzed in six-month intervals cover a considerable range of values (see Table 1). For the highest gasoline priced period (July, 2008), the annual savings for a driver who drives 10,000 electric drive miles (16,100 km) per year instead of a vehicle with the national average of 23 mpg (10.2 liters/100km) is an average of $1,447US. The highest annual savings around the U.S. for this gasoline price period is approximately $1,800US and the lowest is $1,000US. Lower gasoline prices imply considerably lower savings; for example, in one case when gasoline prices were at their lowest (January 2009) the annual savings dropped as far as $100US.

The effect of 100% peak versus 100% off-peak charging is shown in Figure 1 where the difference in annual savings is estimated (for gasoline prices at their historic high of July 2008). Notice that the difference between peak and off-peak charging savings has a maximum of just over $400 per year or an average of less than $1 per day, offering little incentive for drivers to charge off-peak. The authors note that this may have serious policy and GHG emission implications to EV use with current pricing schemes. The relatively weak price signal for consumers to charge off-peak may add to demands on the utility grid during peak periods instead of maximizing the use of surplus electricity supply during off-peak periods. Since additional peak period electricity supplies are often generated by less desirable fuels, particularly in some parts of the country, this could have significant implications for the overall GHG emission reductions and other environmental benefits that EVs can offer *(13)*.

To see how other factors drive more dramatic changes in the savings, refer to the three-dimensional Figures 2(a) and (b). Figure 2(a) shows how changes in gasoline prices have a much more dramatic effect on savings amounts than does off-peak or peak charging. We note that a gasoline tax in increments of $0.50US per gallon would each increase annual savings by more than $200US.

Figure 2(b) demonstrates that EV operational savings are exponential with respect to the fuel economy of the substituted vehicle as expressed in mpg. This is partly due to the assumption that any gasoline vehicle, regardless of fuel economy, is being replaced with an EV that uses 300 Wh/mi (190 Wh/km) for “electric miles” driven. However as the variation in results to conventional vehicle fuel economy shows, these findings are consistent with other studies that note that replacing an already high fuel economy vehicle with a PHEV is less beneficial (with respect to energy and GHG emissions) than replacing an SUV with a PHEV-SUV or even better, replacing an SUV with a smaller EV (*4*). Also of interest is the fact that when a high mileage conventional vehicle is compared with an electric vehicle that is charged on-peak, there is virtually no annual savings. Similarly, switching from a high fuel economy HEV to a PHEV or EV may offer limited benefit.

Geographic Analysis

The authors gathered gasoline prices and subsequent annual operational cost savings amounts were then located on a map of the U.S. This was done for three different dates, each six months apart. The period examined in 2008 to 2009 provided an interesting range of variation with moderate gasoline prices in July 2009, low prices in January 2009, and very high prices in July 2008. It is historically unusual that these extremes are all represented in a one-year period; this incidentally underscores the volatility in the global oil market and the relative stability of electricity prices in comparison. The estimated average gasoline prices used in the study appear in Table 2. Note that several utility company sub-regions had the same estimated gasoline price (such as Hawaii) and are therefore listed only by the parent company.

To get a sense of regional differences in operating costs, the utility and gasoline price regions studied were located on maps of the U.S. and results were plotted on the maps. The maps for each of the three time periods appear in Figures 3, 4(a), and 4(b). Colored circles (textured to be discernable in black and white) represent approximate locations of utility companies but do not represent the magnitude of the jurisdictions. Some circles represent entire states, while others only a city. However, the goal is to show the relative economic climate for EV adoption in various parts of the country. Note that the utility companies that the authors surveyed in the Northeast and Texas present an economic climate less suited for savings from switching to EVs than the West Coast or the Midwest. It must be cautioned that these observations do not represent a comprehensive or random sample of utilities and therefore do not necessarily provide inference for other utility companies not included in this study or for the U.S. in general.

The first map in Figure 3 shows the situation last year when gasoline prices were at their peak (July 2009). EV operational economics during that period are found to be most favorable in the West and Upper Midwest, where annual fuel cost savings of over $1,500US per year are possible. Values in the Northeast typically range from $1,000 to $1,500US per year and from $1,250 to $1,500US in other parts of the country.

Six months later, in January 2009, gasoline prices were much lower. The relative annual savings are shown in Figure 4(a). Note the scale for what constitutes red, yellow, or green (and the textured patterns) are different for all three maps and thus the color or texture codes are not comparable across maps. Note the same basic trends are apparent in Figure 4(a) as in Figure 3. The most recent gasoline prices and their associated EV savings appear in Figure 4(b), representing another six months later (July 2009). Given current prices, only the West Coast and Hawaii remain particularly hospitable to EV operational economics, with annual fuel cost savings of around $1,000US per year.

Study Limitations

This study is relatively narrow in scope, focusing on the difference between fuel costs between EVs and comparison vehicles in different utility service territories. It does not take a broader lifecycle approach as in previous studies that include vehicle capital costs, battery capital costs, and the full range of operating costs—as in Delucchi and Lipman, for example (*14*). Rather this study is meant to contribute to better utility rate understanding and inputs to those study types and to expand over time to become a broader vehicle operating cost assessment model that includes additional aspects of operating cost differences of new vehicle types.

The authors also note that the utility companies used in this study do not constitute a random sample and thus the inference to other utilities is limited. Also, electricity rates were assumed to be the same for the time period examined in the study (mid-2008 through mid-2009). Additionally, no sensitivity analysis was conducted on the energy use (in watt-hours per mile or kilometer) of the EVs and the effect on annual fuel cost savings. Additionally, some “series” PHEV designs have all electric drive and use the gasoline engine only to recharge the battery with a generator after the initial battery charge is exhausted. As these vehicles are expected to be relatively efficient even in this “charge sustaining” mode, they can be expected to offer additional gasoline cost savings compared with conventional vehicles that the authors do not analyze and include here.

Areas for Future Study

This study spurs a host of possible new directions for future research. First, it could be extended with a more comprehensive analysis of national utility rates and their structures in both depth and geographic detail. A look into *proposed* rate structures for companies not currently offering time-of-day rates also could be included. In addition the study could be expanded to formally accommodate commercial vehicles and utility rates and/or heavier vehicles (e.g., delivery vans, airport shuttles, taxis, etc.) with high annual mileage where the potential for savings is greater. Also, as noted above, the authors would like to integrate a more careful assessment of driving patterns and how these would impact both BEV and PHEV miles (km) driven as “electric miles (km),” integrating some of the research being done at Argonne National Laboratory and the National Renewable Energy Laboratory. Battery costs, performance, and subsequent implications on EV economics can be additionally folded into the analysis for better accuracy and more meaningful application. For example, issues raised in the past suggest estimating annual fuel saved per kWh of battery capacity instead of using a 10,000 mile (16,100 km) assumption (*12*). Also, annual savings per dollar cost by type of EV may shed more information on the advantages and disadvantages of each type of EV. The extent that lithium is available may also have implications on the types of EVs and their associated savings.

CONCLUSIONS

The authors find that the variation in EV ownership costs versus conventional vehicles across the U.S. is considerable, ranging typically from several hundred to up to a few thousand U.S. dollars per year. This base case is for a driver who drives 10,000 electric-drive miles (16,100 km) a year instead of a 23-mpg (10.2 liters/100km) conventional vehicle. The higher end of that range (over $1,500US per year) is found only during relatively high gasoline prices, such as those seen during mid-2008. The highest savings around the U.S. for this gasoline price period is approximately $1,800US, and the lowest is $1,000US. Lower gasoline prices imply considerably lower savings; for example, when gasoline prices were at their lowest (January 2009), the least savings observed was only about $100US.

The average savings during the peak gasoline prices of July 2008 is around $1,500US per year suggesting that under a regime where price levels were maintained a PHEV or BEV driven 10,000 miles (16,100 km) on electric fuel could "pay back" (in "simple payback" terms) a $6,000US price premium in four years and a $9,000US price premium in six years. This is absent consideration of other economic differences in vehicle operations associated with battery replacement costs, potential maintenance cost differences, and the higher fuel economy of PHEVs, than conventional vehicles, when operating on gasoline.

For a simple example, the reader could consider a vehicle with a 16 kWh battery pack and with a cost of $15,000US more than a comparable conventional vehicle but that would presently qualify for a federal tax credit of $7,500US. With a fuel cost savings of $1,500US per year (again in a relatively high gasoline price regime), this vehicle would then have a simple payback of about five years. Of course lower gasoline prices—especially the much lower levels observed in early-2009—would extend the potential payback times considerably. The authors note that these payback estimates are consistent with those of other studies, such as *(11)*, which examined various driving cycles and patterns in interaction with PHEV designs, but with a simpler set of electricity cost and gasoline price assumptions, and that also found PHEV simple payback times in the four- to six-year range.

A key finding of this study is that gasoline prices have a more dramatic effect on EV savings than peak or off-peak charging. This is due to the relatively small difference in rates between the peak and off-peak hours. This suggests that the economic incentive may not be there at present, even with TOU rates, for consumers to pay much attention to time-of-day charging (to the extent some flexibility is possible, for example, in the evening). Increasing the difference between off-peak and on-peak rates could help to provide stronger incentives for consumers to charge at off-peak times, thereby reducing potential grid impacts. The sensitivity of annual EV savings to gasoline prices underscores how policy designed to insure a minimum price for gasoline would stabilize EV economics.

Another major finding is that if drivers who currently are driving larger and lower fuel economy vehicles switch to smaller EVs, this would have a particularly strong effect on their operational cost savings as well as on energy consumption and GHG emissions. This is consistent with other studies. Certainly, raising the gasoline price as a policy would help further this agenda. A gas tax in increments of $0.50US per gallon ($0.13US liter) would increase annual savings for EV drivers by approximately $200US for each increment. More importantly, higher gas taxes may motivate drivers to purchase and use smaller vehicles than they are currently, which will have a more dramatic effect on savings, energy consumption, and GHG emissions.

The authors also find that location-specific gasoline prices have some effect on the economic viability of switching to an EV. A combination of electricity rates and gasoline prices give rise to favorable economic climates for EVs in the West and Midwest but not in Texas or especially the Northeast. It is also the case that, owing to their efficiency advantages, EV economics improve with higher usage rates.

Finally, also of note is the fact that a high mileage comparison vehicle when combined with mostly peak-time charging offers virtually no annual savings. Similarly, switching from a high fuel economy HEV to a PHEV or EV may offer limited benefits compared with shifts from lower fuel economy vehicles. This speaks to the need for policy measures designed to provide consumers with market incentives to shift from purchasing conventional vehicles to PHEVs and EVs to focus on the relative improvement in fuel efficiency.

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LIST OF TABLES AND FIGURES

Note to editor: Although some figures are in color, each has been designed to print well in black and white.

TABLE 1 Electric Utility Company and Savings per Year From EV Use—10,000 Electric Miles (16,000 Km) per Year, 23 MPG (10.2 L/100km) Comparison Vehicle, 100% Off-Peak Charging

Power Co.	Region (If Applicable)	Additional Info (If Applicable)	Gasoline Price Date 7/14/08	1/14/09	7/14/09
Pacific Gas & Electric			$1,793	$723	$1,101
Southern California Edison			$1,482	$395	$773
San Diego Gas and Electric			$1,656	$569	$948
Sacramento Muni. Util District			$1,584	$515	$893
LA Dept. of Water & Power			$1,697	$610	$967
Detroit Edison Energy			$1,615	$563	$858
Florida Power and Light Co.			$1,390	$451	$742
National Grid USA	Massachusetts		$1,091	$99	$421
	Nantucket		$1,126	$135	$456
	New Hampshire		$1,208	$229	$551
	Rhode Island		$1,310	$310	$675
	New York	Adirondack	$1,163	$150	$494
		Capital	$1,143	$130	$474
		Central	$1,164	$151	$494
		Frontier	$1,173	$160	$504
		Genesee	$1,172	$158	$502
		Utica	$1,162	$149	$492
Hawaii Electric Company	HEC	Single phase	$1,419	$510	$897
	HELC		$1,612	$704	$1,091
	MEC	Maui	$1,634	$725	$1,112
		Lanai	$1,634	$725	$1,112
		Molokai	$1,634	$725	$1,112
New York State Elect&Gas			$1,334	$321	$665
NSTAR Boston Edison			$1,161	$140	$501
Austin Energy			$1,354	$345	$671
Seattle City Light	Shoreline		$1,697	$623	$1,010
	Seattle		$1,707	$634	$1,021
	Tukwila		$1,691	$617	$1,004
	Suburban		$1,699	$625	$1,012
XCEL Energy	Colorado		$1,454	$445	$771
	Michigan		$1,563	$580	$828
	Minnesota	Overhead	$1,504	$587	$804
		Underground	$1,480	$563	$780
	New Mexico		$1,413	$478	$748
	North Dakota	Overhead	$1,477	$530	$821
		Underground	$1,453	$506	$797
	South Dakota	Overhead	$1,553	$597	$888
		Underground	$1,529	$573	$864
	Texas		$1,461	$501	$766
	Wisconsin	Single phase	$1,532	$601	$832

TABLE 2 Electric Utility Regions and Estimated Average Price per Gallon for Gasoline by Time Period (AAA Data—U.S. Dollars)

Region-Utility Company	7/15/08	1/15/09	7/15/09	Regions Used for Gas Price Estimates
SF-Bay Area (PG&E)	$4.54	$2.08	$2.95	SF, Oakland
Los Angeles (SoCal Edison)	$4.51	$2.01	$2.88	LA, Orange, Riverside, San Bernardino
San Diego (SDG&E)	$4.50	$2.00	$2.87	San Diego
Sacramento (SMUD)	$4.42	$1.96	$2.83	Sacramento
Los Angeles (LADW&P)	$4.51	$2.01	$2.88	LA, Orange, Riverside, San Bernardino
Detroit (Detroit Edison Energy)	$4.18	$1.76	$2.44	Detroit (MI)
Florida (FPLC)	$4.06	$1.90	$2.57	Florida
Massachusetts (Nat'l Grid USA)	$4.09	$1.81	$2.55	Massachusetts
Nantucket (Nat'l Grid USA)	$4.09	$1.81	$2.55	Massachusetts
New Hampshire (Nat'l Grid USA)	$4.04	$1.79	$2.53	New Hampshire
Rhode Island (Nat'l Grid USA)	$4.10	$1.80	$2.64	Rhode Island
New York (Nat'l Grid USA)	$4.31	$1.98	$2.77	New York
Hawaii (Hawaii Electric Co.)	$4.47	$2.38	$3.27	Hawaii
New York (NY State Elect & Gas)	$4.31	$1.98	$2.77	New York
Boston (NSTAR Boston Edison)	$4.08	$1.73	$2.56	Boston (MA)
Austin (Austin Energy)	$3.97	$1.65	$2.40	Austin (TX)
Seattle (Seattle City Light)	$4.35	$1.88	$2.77	Seattle (WA)
Colorado (XCEL CO)	$4.07	$1.75	$2.50	Colorado
Michigan (XCEL MI)	$4.18	$1.92	$2.49	Michigan
Minnesota (XCEL MN)	$3.97	$1.86	$2.36	Minnesota
New Mexico (XCEL NM)	$4.05	$1.90	$2.52	New Mexico
North Dakota (XCEL ND)	$4.06	$1.88	$2.55	North Dakota
South Dakota (XCEL SD)	$4.05	$1.85	$2.52	South Dakota
Texas (XCEL TX)	$3.97	$1.76	$2.37	Texas
Wisconsin (XCEL WI)	$4.09	$1.95	$2.48	Wisconsin

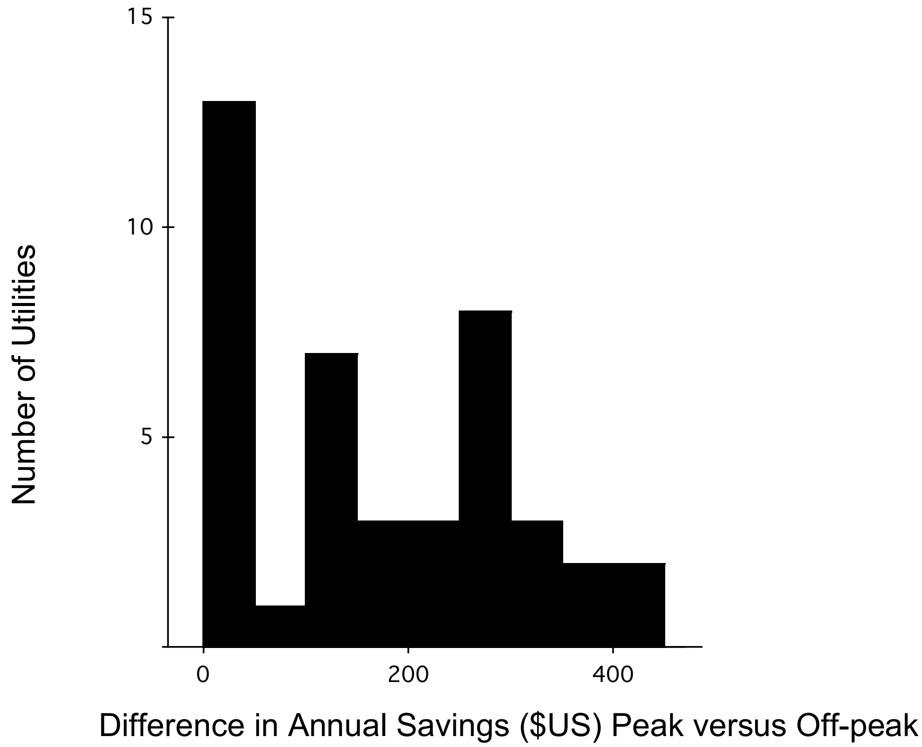
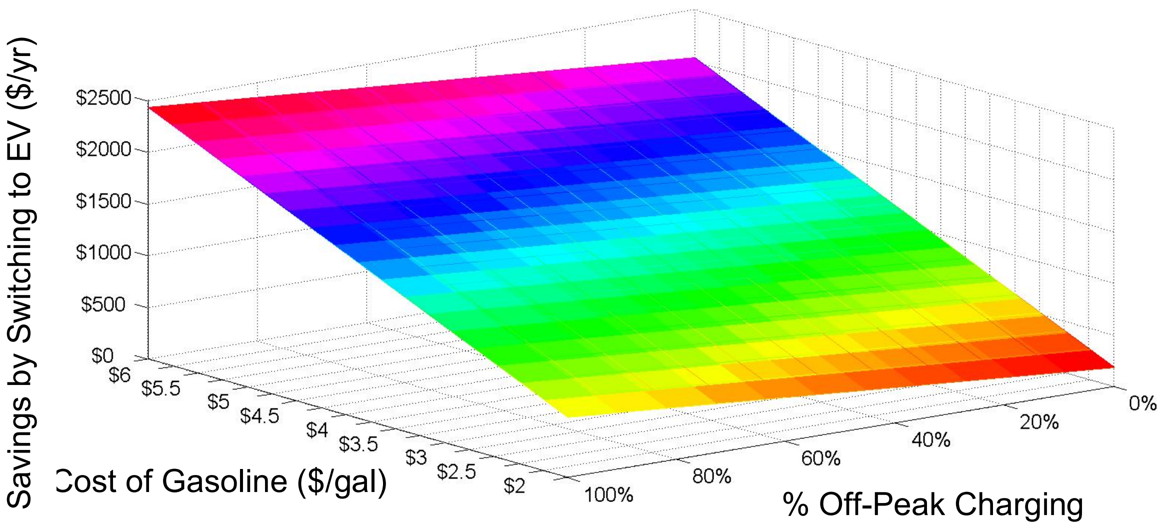
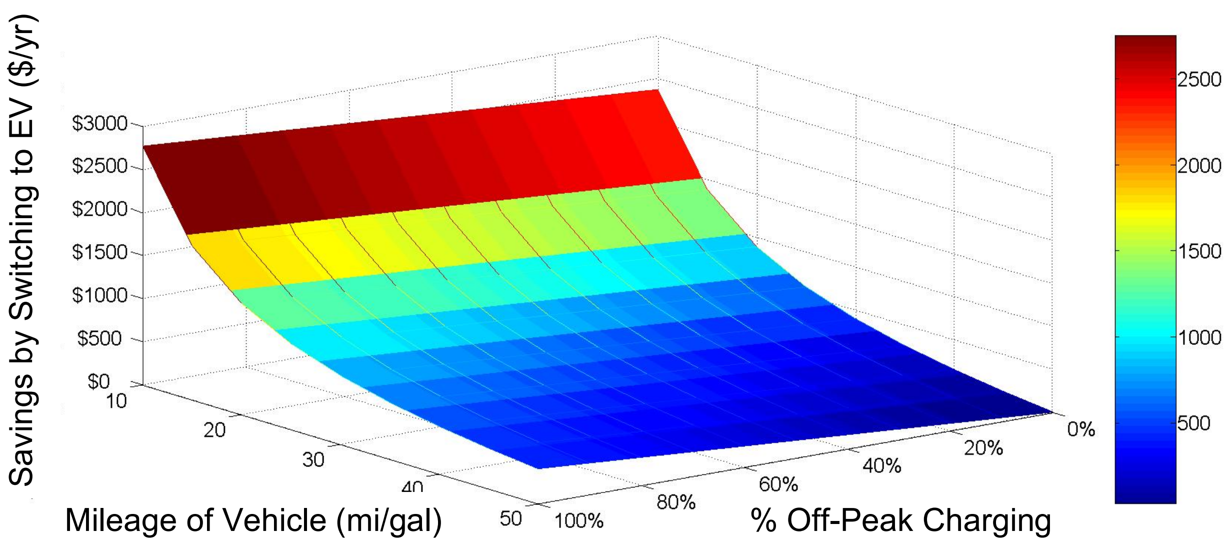


FIGURE 1 Histogram of difference in annual savings ($US) per year from EV charging peak versus off-peak for 10,000 electric miles (16,000 km) per year, 23 mpg (10.2 liters/100km) comparison vehicle, and July 2008 gasoline prices.



(a) By Gasoline Price and Charging Pattern for 23 mpg (10.2 L/100km) Comparison Vehicle



(b) By Comparison Vehicle Fuel Economy and Charging Pattern

FIGURES 2 (a) and (b) annual operating cost savings (US$/yr) for example utility PG&E for 10,000 electric miles (16,100 electric kilometers) per year.

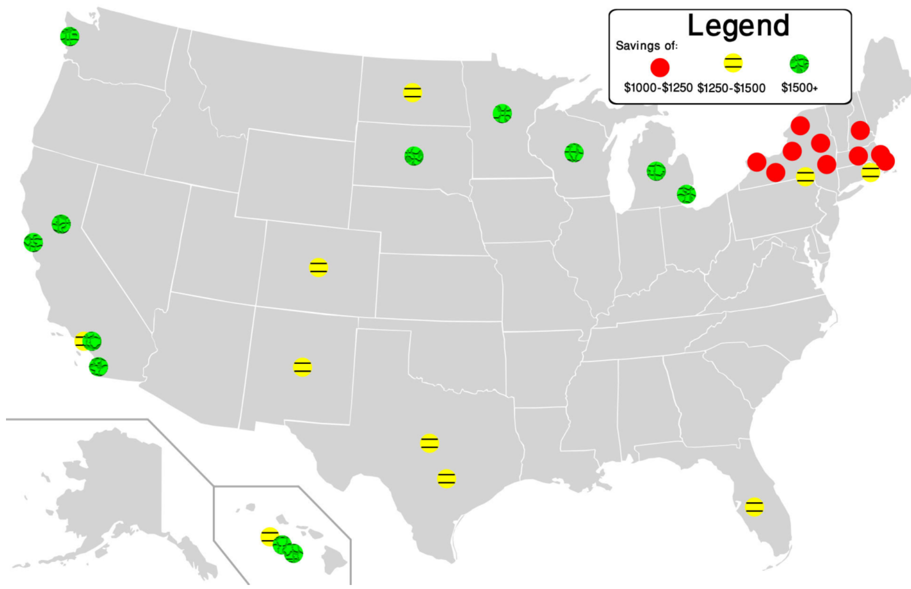
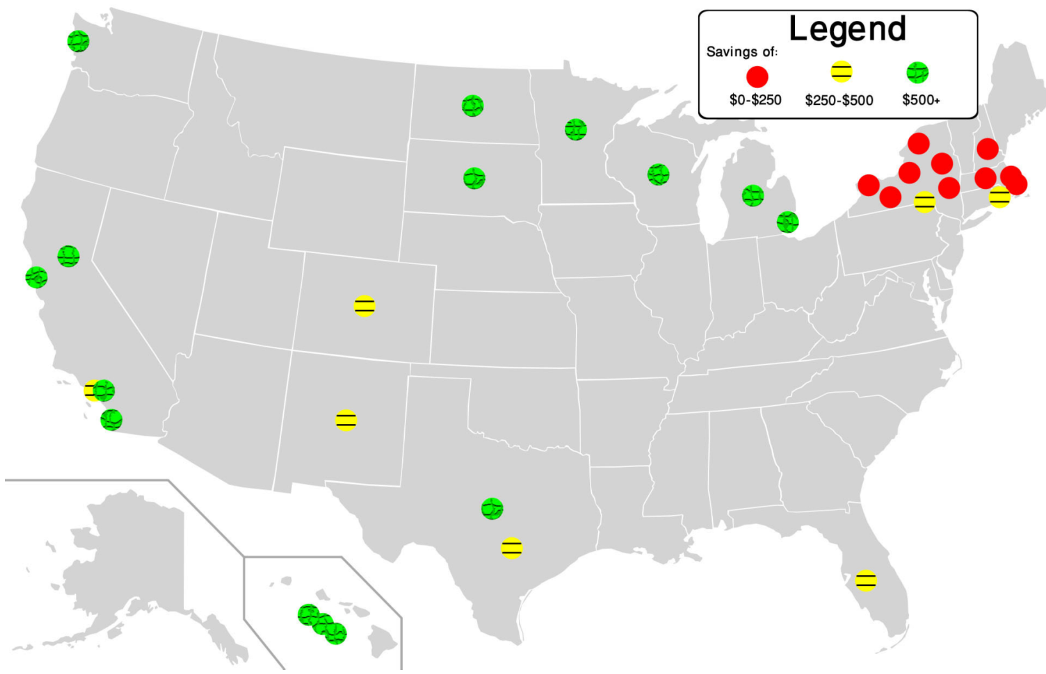
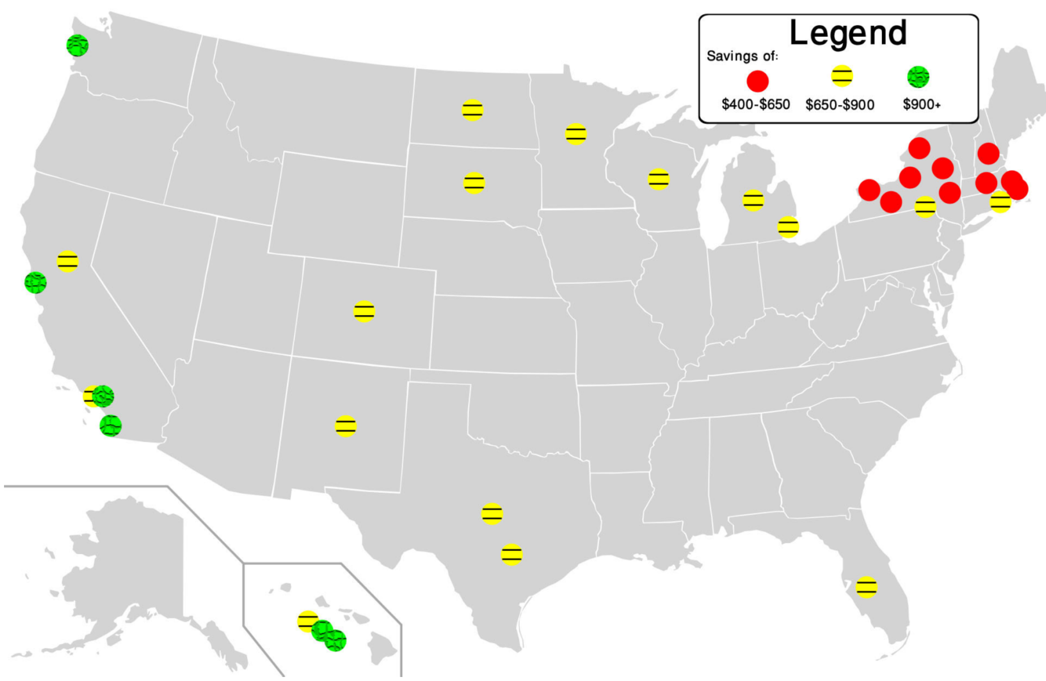


FIGURE 3 Relative annual fuel cost savings from switching to EVs based on estimated gasoline prices in July 2008 (10,000 electric miles/16,100 electric kilometers per year and comparison vehicle with 23 mpg/10.2 liters/100km).



(a) January 2009 Low Prices



(b) July 2009 Most Current Prices

FIGURES 4 (a) and (b) Relative annual fuel cost savings from switching to EV based on estimated prices of gasoline for 10,000 electric miles (16,100 km) per year and comparison vehicle with 23 mpg.