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Charging for Charging at Work:
Increasing the Availability of Charging Through
Pricing

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ABSTRACT

A survey of plug-in electric vehicle (PEV) owners was conducted focusing on workplace charging suggesting that pricing could increase the availability of charging by excluding those who could charge at home. Respondents reported that in California, 38% of drivers who have chargers at work are unable to charge at least once per week due to congestion at chargers. When asked about price, answers indicated that 4 chargers would be needed for every 10 vehicles if free, versus 1 charger for every 10 vehicles if the price were double that of home electricity (assuming 1 charger serves 2 cars/day). Since double the price of home electricity is still likely to save money, the implication is that people are using free workplace infrastructure 4 times more than they need to. This usage pattern suggests that simply charging a small fee could encourage more efficient use of infrastructure.

INTRODUCTION

Plug-in electric vehicles (PEVs) consisting of both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are rapidly entering the marketplace and policy makers are seeking ways to increase their sale and likelihood of use. Increasing the availability of workplace charging has been identified as a one strategy to increase the sale and use of EVs and this effort is represented by the EV Everywhere Workplace Charging Challenge [1]. In a recent survey of about two thousand PEV users, the majority report that workplace charging is currently free (Figure 1), but should it be?

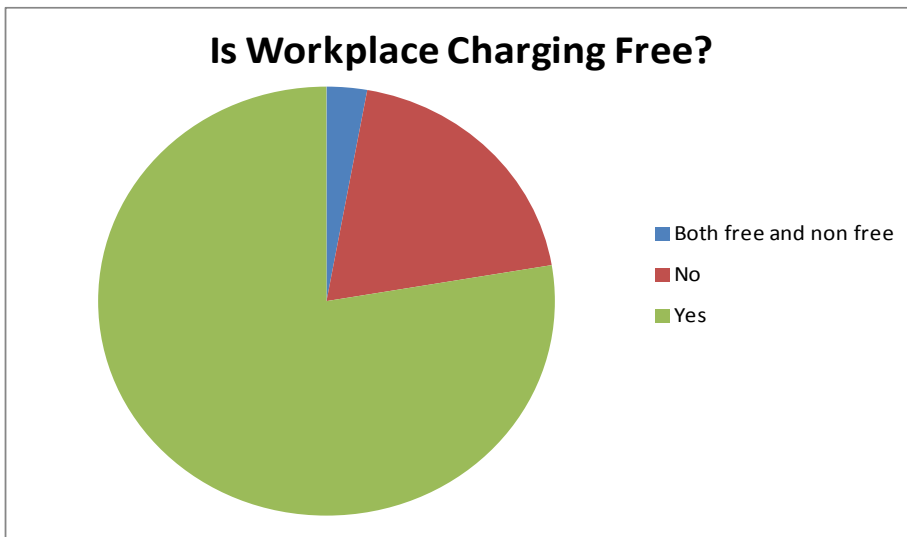


Figure 1 Workplace charging landscape. 78% of respondents report free charging.
Source: UC Davis/CCSE Survey, May-June 2013

While making workplace charging free may increase the purchase of PEVs, there is evidence that free workplace charging does not increase electric vehicle miles traveled (eVMT) for many users versus a priced scenario. Congestion already exists at some chargers, and more effective use of those chargers could enable more eVMT. Early evidence suggests that congestion at chargers is reducing dependability and consequently preventing BEV users from using their vehicle further reducing eVMT. This paper is meant to explore this topic and present the pros and cons of free workplace charging in the context of survey responses.

Pros of free workplace charging

- Potentially increases plug-in electric vehicle sales
- Simplifies charger installation and setup for the workplace
- Avoids administrative hassle of collecting revenue
- Avoids impression of pettiness of employer
- Provides employees a workplace benefit

Cons of free workplace charging

- May switch charging from home to work
- May not appreciably increase eVMT over a priced scenario
- Can create congestion at chargers more quickly than a priced scenario
 - Decreases dependability for BEVs, discouraging certain trips
 - May decrease purchase desirability of a BEV if charging is not dependable
 - Potentially requires expensive panel upgrades to keep up with demand
 - Demand for free chargers may outpace practical installation rates

In the context of these factors, this paper explores using pricing to manage workplace charging. Pricing need not be designed to provide capital recovery on electricity and installation cost, but simply to discourage those who do not require charging from using it. Furthermore, if the price for charging rises past a price threshold of 16¢/kWh - 23¢/kWh depending on gasoline prices, it will be cheaper for an efficient PHEV to drive on gasoline. Free charging may still be desirable for a short time during the market launch phase of PEVs. However, it is likely unwise for charging to remain free at work in perpetuity. If PEVs become a large part of the market, more efficient use of home charging will become necessary, reserving workplace charging for those who need it the most.

LITERATURE REVIEW

There have been a few studies looking at the potential benefit of workplace charging and its potential usage [2,3,4]. Few, however have looked at the effect of pricing on the number of chargers needed [5,6,7]. Economics, however, suggest that if a resource is free then it will be used more than an equal service that is not free. In the case of EV charging, the choice is often between a home charger at home electricity prices, and a work charger for free. If the work charger is used more often, then more work chargers will be “needed” to satisfy demand. To help answer the question of needs versus wants, we asked respondents in a survey how often they would use workplace charging under different pricing scenarios.

SURVEY RESULTS

UC Davis and the California Center for Sustainable Energy (CCSE) partnered on a survey administered on behalf of the California Air Resources Board that address the pros and cons of free workplace charging listed in the introduction. This survey was conducted in May-June 2013 of PEV owners revealing usage of and opinions on workplace charging by vehicle type. Figure 2 shows the prevalence of workplace charging and Figure 3 shows the pricing of current workplace charging based on the results of this survey.

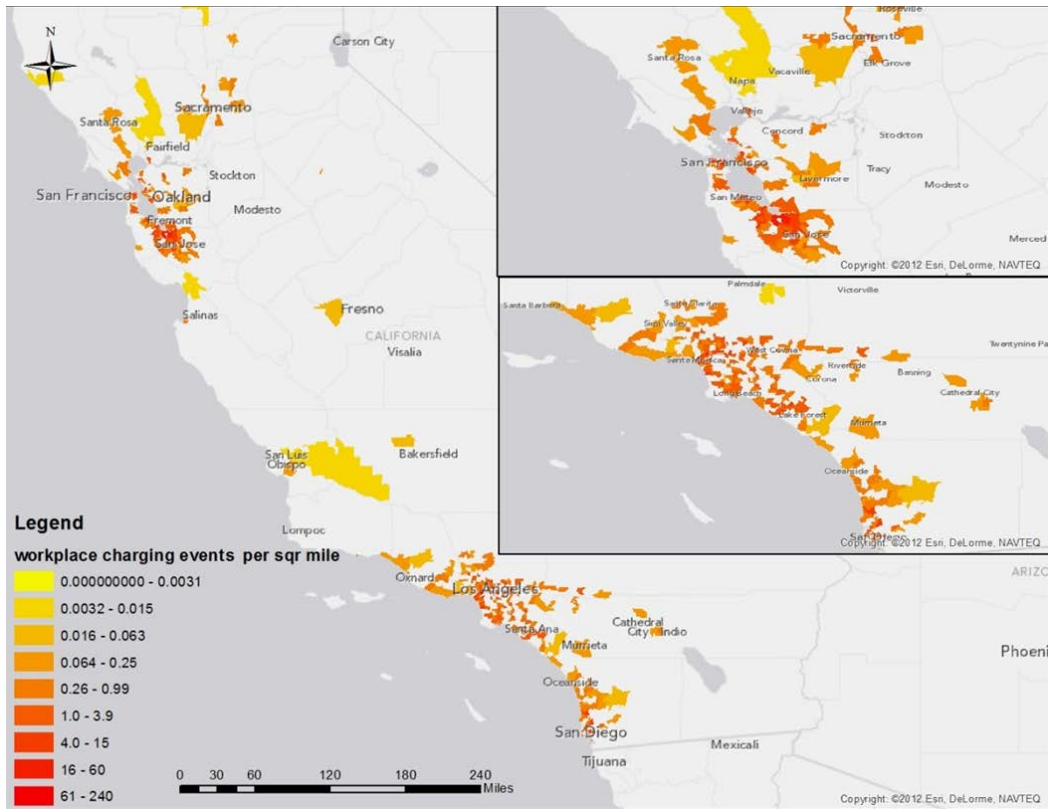


Figure 2 Density per square mile of workplace charging events with a minimum of 5 respondents per zip code.

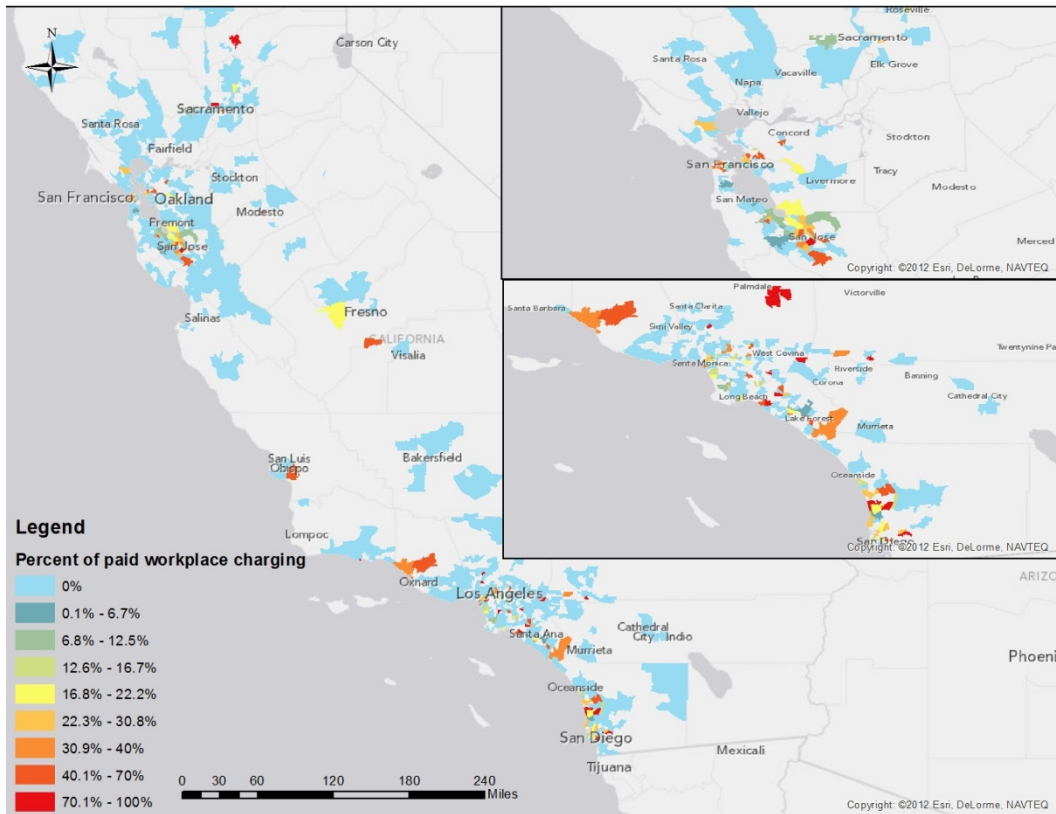


Figure 3 Zip codes where workplace charging was present (no minimum number) and the percent of which was paid and free

Figure 3 shows that there are some areas that do have paid charging, and those light blue shaded areas have exclusively free workplace charging. Although not specifically asked in the survey, most paid workplace charging is likely in public lots near the workplace rather than lots owned by the workplace.

The survey indicates that there is already congestion at work chargers and 38% of those who report workplace charging availability report congestion at chargers at least one day a week. For example, in the San Jose area (Figure 4) on many days people reported not finding chargers reliably at work. Interestingly, the location of the paid charging in Figure 3 in many places is correlated with the congestion shown in Figure 4. What may be happening is a maturation of the charger market and that a strategy to deal with congestion is paid charging. The implication is that if congestion requires paid charging, policy steps may be taken in advance of congestion to improve charger dependability.

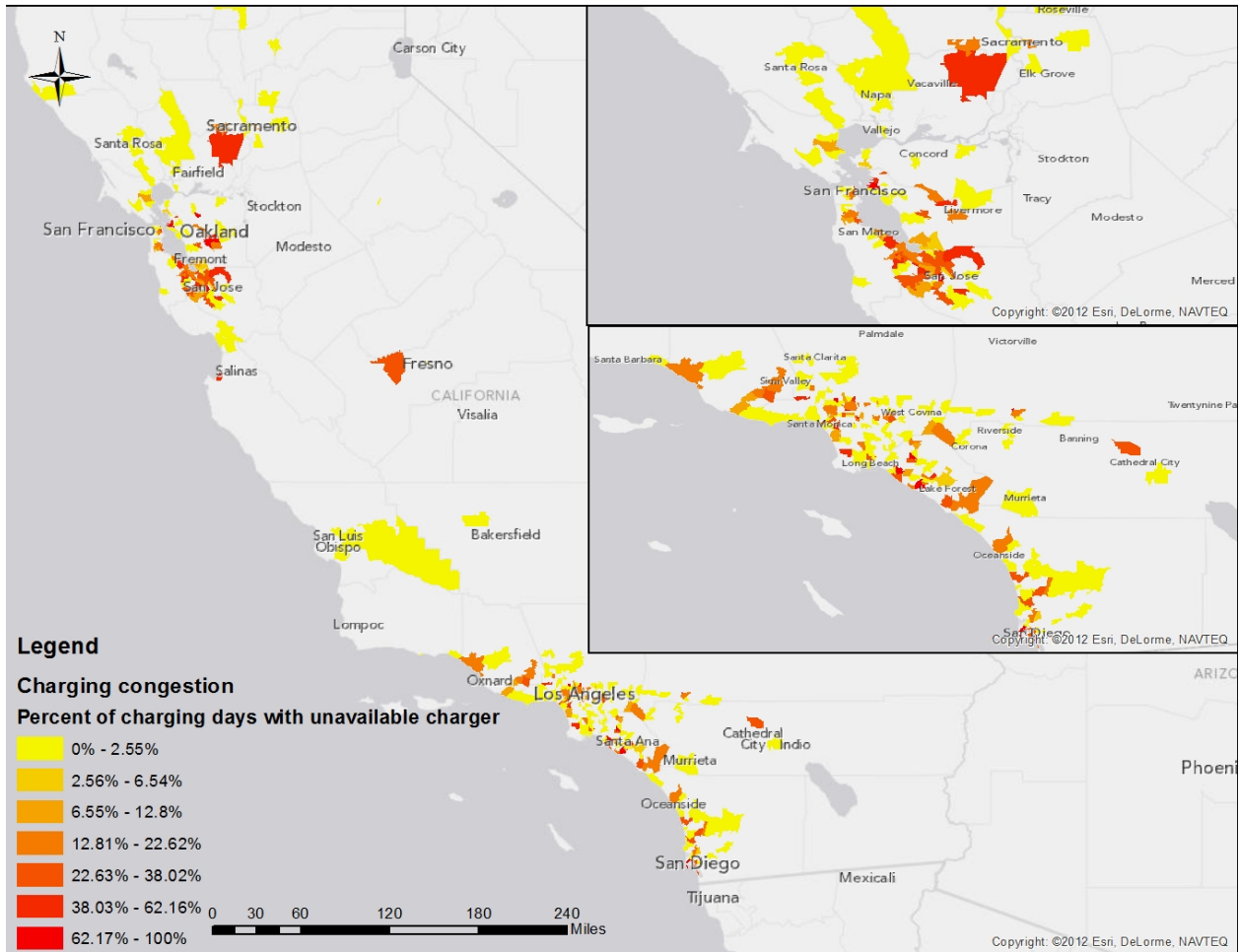


Figure 4 Congestion at workplace chargers by zip code. Minimum 5 respondents per zip code.

Figure 4 shows that charging cannot be depended on reliably at work in many areas. Those who need charging may not be able to find it. In the sections below, further details about the survey and its relation to work charging are presented.

Pros of Free Workplace Charging

Free Charging Increases Vehicle Sales

Free charging does have an initial benefit that should not be understated. Anecdotal evidence suggests that dependable free charging increases vehicle sales. If vehicle sales are the ultimate goal of providing free charging, then a never ending supply of free chargers will accomplish this goal.

We see from respondent comments in the survey that free charging has a strong appeal to make an investment in an electric vehicle.

“Main decision to purchase my Volt was based on my work currently allowing free charging. If they did not provide free charging, I would not have purchased my Volt or other electric vehicle.”

However, if the supply of chargers is practically limited by installation and money, eventually, free charging could stifle the market as chargers become more congested and BEVs are not able to depend on being able to charge at work. Because drivers cannot depend on chargers when they need them, the marketability of a vehicle could eventually decrease.

Free Charging is Cheaper to Maintain and Simpler to Administer

There are many reasons employers may have for not administering a fee for charging, these include:

- The cost of electricity is negligible
- There is not an easy mechanism for collecting charging fees to justify the hassle for administration
- The cost of administration is more expensive than the cost of electricity
- Charging creates the impression of pettiness on the part of the employer
- Free charging gives the appearance of corporate sustainability for the lowest initial cost regardless of effectiveness for users

All of these are considerations that will affect the decision to provide free or paid charging, but ultimately, having only free charging may be short-sighted. Oftentimes, businesses go through the hassle of installing chargers only occasionally. Companies may install a few chargers initially, but hiring contractors to install additional chargers is an expensive, time-consuming process. Even though the electricity is cheap, the chargers and installation are not. Free chargers quickly fill up with users regardless of need.

The mechanism to charge money admittedly may be more complicated. Low cost options for a monetary structure do exist, but oftentimes workplaces are not aware of them. Additionally, the fee for charging could be used to recover the cost of administering the fee itself, which has the potential for the system to be revenue neutral. However, whatever the costs may be, they could be small compared to the costs for installing more new workplace chargers. This is an opportunity for policy to direct effort to providing guidelines on best practices.

Cons of Free Workplace Charging

Switching from Home Charging to Work Charging

Evidence from the 2013 survey suggests that users switch from home charging to workplace charging as much as possible if it is free, whether it is needed or not. Taken to its logical extension, free charging creates the situation where chargers are occupied with cars who do not need charging, leaving those who need charging unable to depend on it. Figures 5-7 show three responses to pricing scenarios that illustrate the potential switch from home to free workplace charging. Looking at Figure 5 for the Plug-in Prius, we see that 80% of respondents would plug in four or more times per week if it were free, but only 13% would plug in with the same frequency if it were double the price of home electricity. Similar patterns are observed for the Volt, while Leaf drivers demonstrate a higher willingness to occasionally pay for charging.

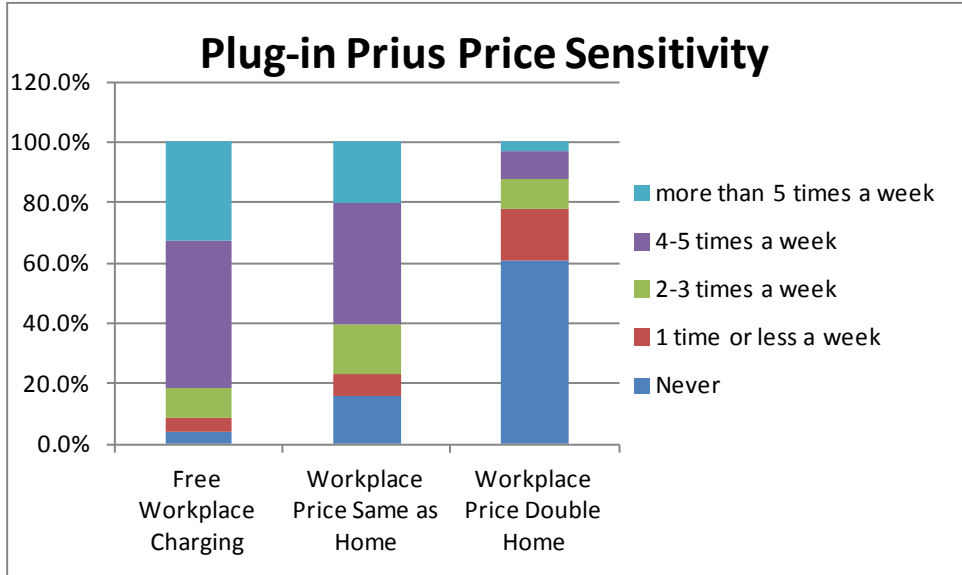


Figure 5 Percentage of Plug-in Prius respondents who would plug in under different pricing scenarios

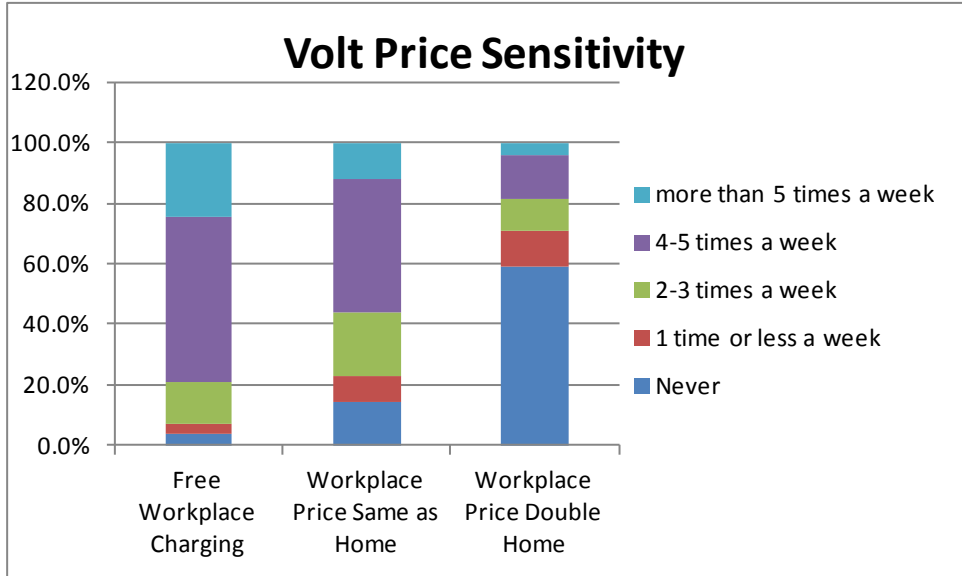


Figure 6 Percentage of Volt respondents who would plug in under different pricing scenarios

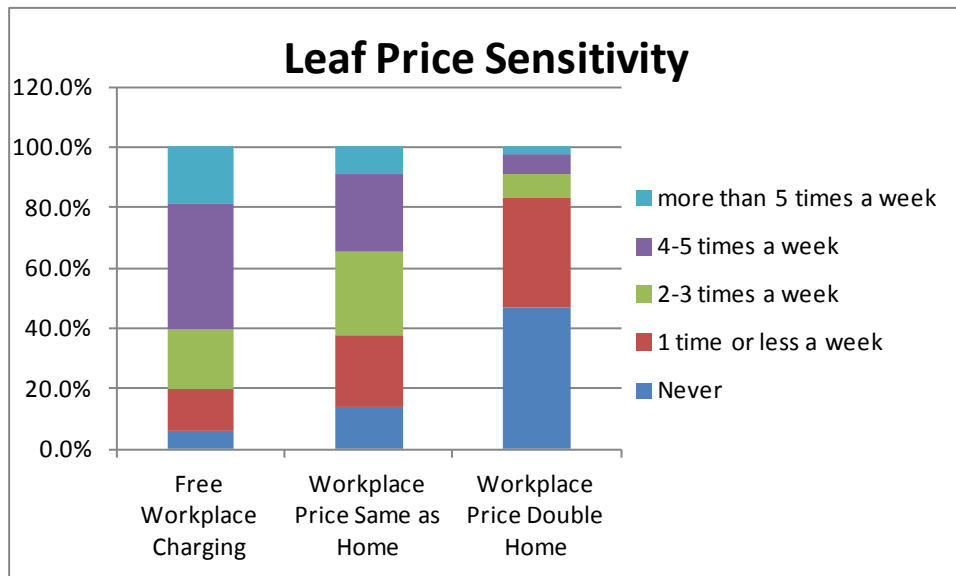


Figure 7 Percentage of Leaf respondents who would plug in under different pricing scenarios

Casting the prices in terms of home electricity was done as a matter of convenience rather than to translate the costs into cents per kWh or cents per mile. However, phrasing the question this way is meant to highlight one parameter: will consumers plug in at home or at work? Each of the three pricing scenarios has a unique rationale: free workplace charging represents the economic incentive to arbitrage electricity prices; equal pricing represents how many people could get meaningful benefit for the inconvenience of plugging in; doubling the price represents how many people need the charge to either return home or save money on fuel costs. Since price parity on a cents per mile basis is about 21 cents per kWh for a Prius (assuming \$3.66 per gallon gasoline, 50 MPG, and 2.819 mi/kWh), driving on gasoline may be the rational choice in certain pricing scenarios.

Free Charging Could Quadruple Usage and Drive Up Infrastructure Costs

Ultimately the switch from home to free workplace charging could create two problems: vehicles are charged in the day versus the night (creating the potential for grid infrastructure stress or increased emissions in some areas) and providers of workplace infrastructure should expect to need 2-4 times the number of chargers they would need under a priced scenario. Oftentimes, a large number of chargers requires costly upgrades that might otherwise be avoided. As an example, using the preferences above assuming a fictitious U.S. market of 33% Plug-in Prius, 33% Chevrolet Volt, and 34% Nissan Leaf we can make some representative calculations on the number of chargers and possible investment required in different scenarios. Assuming that a Level 2 charger can serve on average of 2 cars per day and drivers charge with the frequency in the free scenario above, 41 chargers would be needed per 100 vehicles. With a price equal to home, 32 chargers would be needed. With a double-priced scenario 11 chargers would be needed. These estimates will double if only one car per day uses the charger.

Free Charging May Decrease Dependability for BEVs

Dependability is an important factor when deciding to buy or use a BEV. The range of the vehicle limits what driving can be done but charging can address some of these limitations and give confidence to the driver that he or she can complete a journey. When deciding to buy a vehicle, customers may consider

dependable charging as a factor in whether a BEV will meet their travel needs, and in turn influence their purchase decision. Dependable charging also affects the use of the vehicle on any particular day. On longer travel days, if there is a doubt as to the ability to complete a trip with a BEV, then a gasoline vehicle may be chosen – if another vehicle is even available.

We see evidence of the importance of dependable charging in Figure 8 by comparing the willingness to pay for charging at double the cost of home electricity.

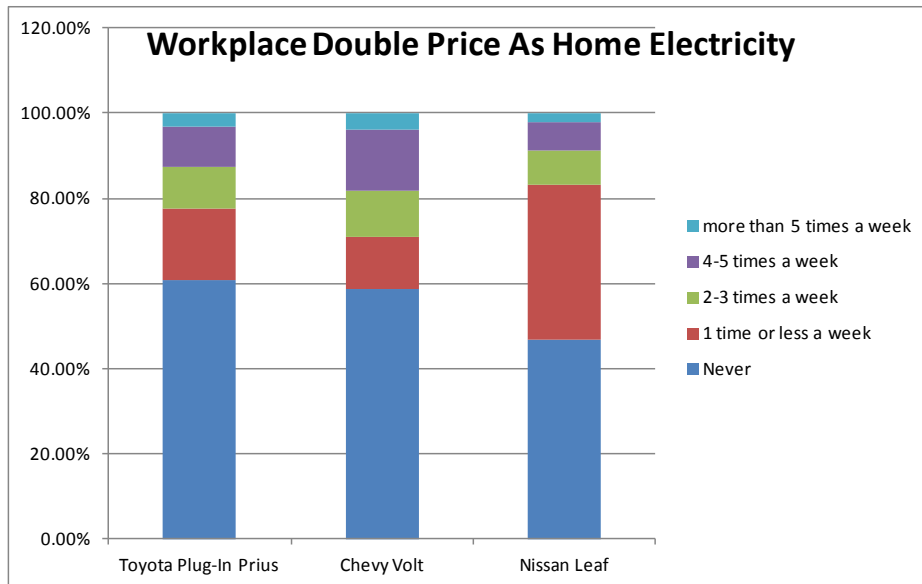


Figure 8 Expected charging frequency assuming workplace charging were double the price of home electricity.

One of the most striking features is the willingness of Leaf drivers to occasionally (1 time or less per week) pay double for charging relative to the other vehicle types. This makes sense since as Leafs have few options on longer travel days other than to charge to complete their trips. In this case, dependability of charging is of higher value for BEVs than for other vehicle types. This suggests that a charging fee may actually help Leaf or other BEV drivers.¹ However, another interesting finding from survey responses is that less than 20% of Leaf owners would charge more than once per week. Overall, these two points combined imply that Leaf owners would need fewer chargers at workplaces than other vehicle types, preferring to charge at home in normal circumstances. These chargers, though, may need to be more dependable in terms of their availability.

The comment below highlights two issues related to dependability: chargers are getting congested (possibly because they are free), and that dependable workplace charging is important in extending the range and functionality of the vehicle.

¹ Additionally, improved dependability of workplace chargers can benefit PHEV owners who do not have access to home charging. In this case, charger availability is doubly important. If those who do not need the charging are using the chargers, PHEVs who have no other source of charging may be forced to run on gasoline.

“In the time I've had the Leaf, the infrastructure has gotten much better. In the past year my employer installed 12 free level 2 chargers. That really was a game changer for me extending my practical range and allowing me to be far more liberal with my use of the heater in the winter. At first I was the only one using any of the chargers. Now they are almost always occupied. Parking services is looking into a 4 hour time limit for charging which seems fair.”

Although not specifically stated, the comment above highlights that employers may have many chargers fill up very quickly if the charging is free. Another commenter directly states that reliability is becoming an issue

“The charging infrastructure and reliability and availability have been lacking and is becoming more scarce due to the growing number of Plug in hybrids.”

Another Leaf commenter shows the willingness to pay for dependability up to the price of gasoline.

“As for what I would pay, I'd pay as much as gas prices if chargers were everywhere just so I don't have to worry about not having the ability to charge my car. I would only use it in an emergency or long road trips but I'd pay that amount to be able to use my electric car more. I love my car! We have a 4 year old and had twins right after buying the car and we use it exclusively to drive the family around. We like to say we fit everything but the nanny in the Leaf!”

DISCUSSION

How much should be charged at work to ensure the efficient use of chargers? To preserve the economic benefit of driving on electricity, charging should be priced between average home electricity price and the price of gasoline. Level 2 chargers could be priced at 15¢ to 21¢/kWh. These prices are not meant to provide capital recovery or even recovery on electricity, but to encourage drivers to make better use of home chargers if available. If charging were priced at the home rate of 15¢/kWh then there would be no incentive to charge at work unnecessarily. Some have an EV home rate of as low as 6¢/kWh and so at a 15¢/kWh price, drivers would have little incentive to charge at work. However, as shown in Figure 9, even a Prius would save money up to a price of 21¢/kWh at work assuming \$3.66/gallon of gasoline.

Figures 2-4 show that 80% of drivers would use a free charger daily, but only 20% would use it daily if it were priced double that of home electricity. Factoring into these choices is commute distance, battery size, home electricity price and gasoline price. Singling out which factors are responsible for the choices is difficult, but Figure 9 puts the last 2 factors, electricity price and gasoline price into context for different car models on a cents per mile basis.

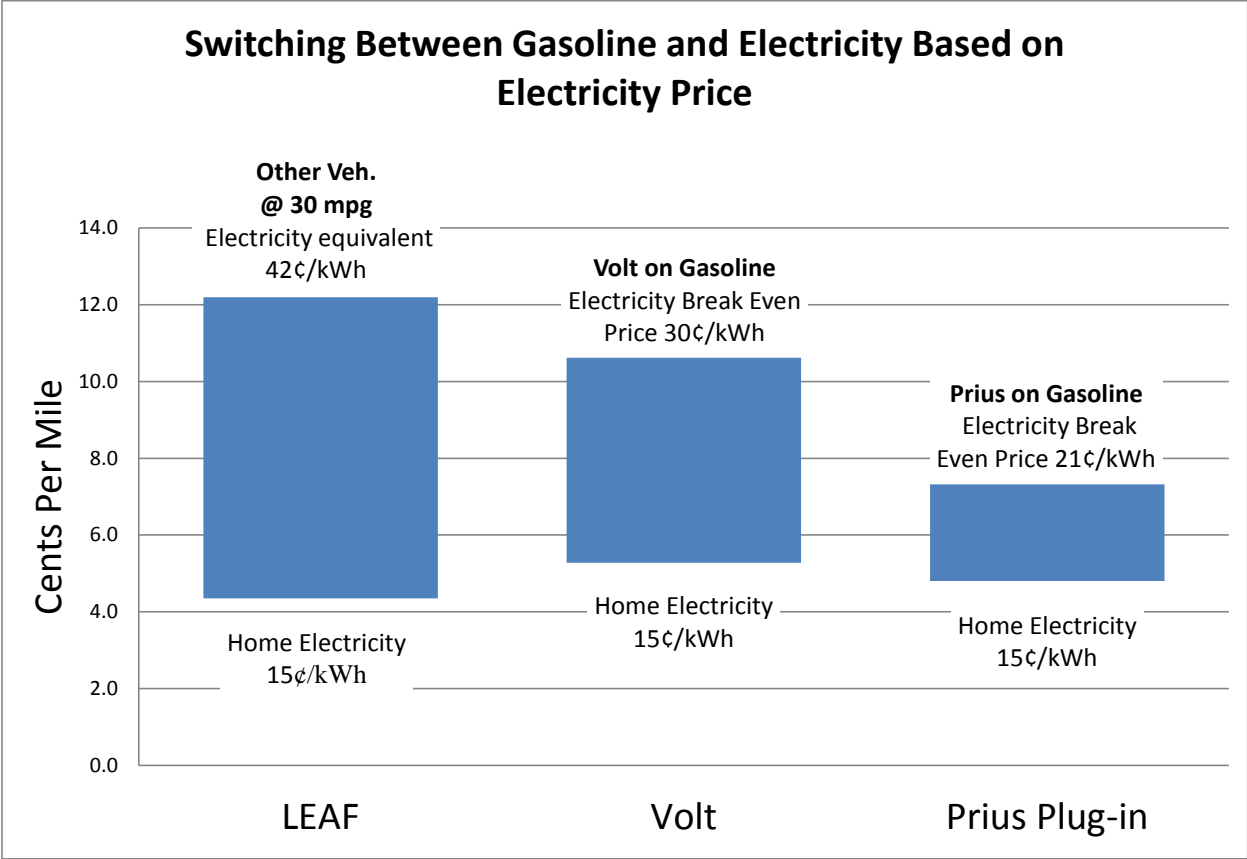


Figure 9 Electricity breakeven price points when arbitraging electricity against gasoline[8].

For the Plug-in Prius, the range of prices above home electricity (>15¢) and below the break even gasoline price (21¢) is smaller than for other vehicles. Also the battery is smaller, so the benefit of plugging in can be very small. To fill an entire battery at 4.4 kWh (useable capacity is actually less), the user can save about a dollar versus driving on gasoline if the charging were free, if the driver were paying home electricity prices, then the savings over driving on gasoline are 32¢ per charge event. The situation is different for the Volt. If charging were free, then to fill an entire 13kWh battery, this saves \$3.90 over driving on premium gasoline. If paying the same as home electricity, the owner saves \$2.10 over driving on premium gasoline.

CONCLUSIONS

Free charging provides the benefit of increasing sales, but the disbenefits of potentially shifting charging from home to work, and creating congestion at chargers. Because of this, some amount of free charging may be desirable to initially spur the market. To create dependability in the system for those vehicles that need charging, pricing at a rate higher than average home electricity, but lower than gasoline cost could be used to preserve the economics of an EV while reducing congestion at chargers.

The cost per mile of an efficient vehicle caps the price a workplace can charge to a very low level, so cost recovery for the workplace may not be possible. Pricing on the other hand could still be used as a way to ensure the efficient use of chargers and encourage users to charge at home if possible.

Other strategies that don't require charging a fee can be used in this scenario as well. Time limits on chargers can be instituted as a low cost strategy, but may still result in a shift from nighttime charging to daytime charging and create congestion were it might otherwise be avoided.

There are some limitations to the pricing suggestions in this analysis. The price for home electricity is based on a tier system in many parts of the State making home electricity price variable. Since PEVs use a great deal of electricity, the price of home electricity may be high if charged at home and the user does not have a special EV rate. EV rates should help a PEV owner reduce costs of off-peak electricity, but there are some cases when any load added to a home is expensive. In this case there may be some difference in the assumptions vs. the actual price of electricity and corresponding behavior. However, pricing will still create a more efficient use of chargers.

If chargers are consistently available, drivers can depend on them. In the case of BEVs, this is especially important as higher power can at times mean the difference between being able to complete a journey or not. BEVs become much more viable as a transportation choice and this increased dependability could increase sales similar to the increase caused by free charging.

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