The Impact of Incentives on Electric Vehicle Adoption

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This work estimated the potential impact of electric vehicle incentives on electric vehicle adoption rates from 2020 through 2030. It differed from previous work in this area in that it focused specifically on utility incentives and was able to deliver results on a national as well as a regional basis.

Keywords—Plug-in-hybrid-electric-vehicle (PHEV), battery electric vehicle (BEV), transportation electrification, EV incentive, EV adoption, MA3T

I. Introduction

Electrification of the transportation sector could provide significant environmental benefits and cost savings to consumers. Electric utilities could play a critical role both in generating the electric fuel that would power this new transportation paradigm and in managing the infrastructure through which it is delivered. Utilities are therefore exploring potential ways they could accelerate adoption of electric vehicles (EVs).

The purpose of this study is to estimate the potential impact of utility initiatives as well as other variables outside of utility control to help enhance and predict adoption rates between 2020 and 2030. The following features of this study distinguish it from previous EV adoption research:

- A specific focus on the impact of utility incentives for EV adoption
- Primary research with customers of eight utilities spanning 13 states, with significant regional variation, a mix of rural and urban geographies, and markets that are both leading and trailing in EV sales
- EV adoption projections that are based on the coupling of discrete choice analysis of consumer preferences, with a detailed adoption model that accounts for fundamental market trends in fuel prices, vehicle stock turnover, and other factors.

This study's assessment of the impacts of new incentives on EV adoption for various customer segments provides a useful basis for developing targeted EV marketing and customer outreach efforts.

II. Methodology

A. Discrete Choice Model and Survey

In order to obtain information on consumer preferences for each participating utility, a survey was conducted though YouGov, a for-profit company in the area of consumer surveys. The survey collected information about the influence of certain factors on the likelihood that a consumer would purchase an EV in the future. The factors were chosen to address areas that are under-researched, likely to have a significant impact based on a literature review, and of interest to the eight participating utilities. The survey tested the effects of 8 different factors on EV adoption namely:

- Purchase Price Reduction
- High Occupancy Vehicle Lane Access
- Reduced Electricity Price
- Green Electricity Rate
- Home Charger Incentive
- Free Public Parking
- Workplace Charging
- Public Charging Station Density Increase.

Survey respondents were asked to make hypothetical choices among three versions of the same vehicle: a new conventional internal combustion engine (ICE), a new battery electric vehicle (BEV), and a new plug-in hybrid electric vehicle (PHEV) that retains the ability to run on gasoline after depleting the energy in the on-board battery. Each of the vehicles in the survey were presented with different incentives that the survey taker weighed in their vehicle choice. The type of vehicle presented to the survey taker was based on information of their previous vehicle purchases to hopefully present a purchase option that the survey taker found appealing. The survey was filtered to only include those who planned on buying a new car in the next 5 years. The used vehicle market was excluded. The surveys were structured to enable conjoint choice experiments. An example choice matrix is shown in Fig. 1 below.

Comparison 1

2018 Honda Civic

	2018 Honda Civic-plug-in hybrid	2018 Honda Civic-electric	2018 Honda Civic
Powertrain definition	Plug-In Hybrid	All-electric	Gasoline
Purchase price ($) definition	$35,908	$35,908	$23,939
Home Charging Program available? definition	Yes ($0 equipment charge)	Yes ($0 equipment charge)	NA
Fuel cost ($/mi) definition	$0.04	Free	$0.07
"Green" electricity guarantee? definition	No	No	NA
Option to charge at work? definition	Yes	Yes	NA
Public charging station density (relative to gas station density) definition	1 charging station per every 2 gas stations	1 charging station per every 2 gas stations	NA
Perks definition	HOV Acess + Free Parking	HOV Acess + Free Parking	NA
Range (mi) definition	Battery range 25 mi Total range 300 mi	250	425

Fig. 1. Example choice matrix from the survey. Survey takers were presented with 10 choice matrices during the survey.

As with any survey study, it is hard to say whether someone will actually behave as they say they would in the survey. To try to get a more realistic response, after each matrix selection, survey takers were presented with the question, 'Would you like to purchase the vehicle that was just selected?'. While they may have chosen the vehicle that most appealed to them out of the three offered, they may still not want to purchase that vehicle and this follow up question gave them the ability to opt out of their choice.

One unique feature that helped decide which analysis to use for this project was the fact that through the discrete choice (DC) method survey takers could be asked about their willingness to purchase vehicles that may not exist yet. For example, if someone who traditionally purchases a truck took the survey, they would be asked about their willingness purchase an electric equivalent even though there isn't one currently available for sale. If the survey taker answered yes, then the results would identify a future inflection point in adoption such that once an electric truck is available in the mass market (all other things such as purchase price being equal) there may be another pool of potential EV adopters.

The survey was conducted online in 8 utility territories across the United States. The number of surveys conducted in each utility territory was chosen so that the sample size was large enough to derive statistically significant results on a utility by utility basis. 400 surveys were conducted in each territory, totaling 3200 surveys.

B. *Modeling Tool*

The study relied on ORNL's MA^{3}T model [1] to establish a baseline forecast of EV adoption (ORNL "MA^{3}T Model"). MA^{3}T is a Microsoft Excel based market simulation model that forecasts adoption of advanced technology vehicles over a multi-decade time horizon. The model uses vehicle and fuel costs and a representation of customer behavior to estimate how quickly new automotive technologies will be adopted. The attributes of technologies and consumer behavior represented in the MA^{3}T model include technological learning by doing, range anxiety, access to recharging points, daily driving patterns, and willingness to accept technological innovation. MA3T was first compared to other EV projection models and was also calibrated on a utility by utility basis to local EV sales.

The DC and MA^{3}T models were combined to produce an integrated EV adoption forecasting model. This allows the baseline EV adoption forecast from MA^{3}T to be adjusted to account for the impacts of user-defined incentives for EV adoption. The final modeling tool was able to model varying EV incentives on a regional basis.

III. RESULTS

A. *National Survey Results*

Nationally, out of all the potentially new vehicle owners, most (90%) preferred to buy the car rather than lease it and when it came to potential purchase price, the majority (50%) were looking for a vehicle in the price range between $20,000 to $40,000. 40% of respondents preferred a vehicle purchase price less than $20,000. Only 2% of the respondents preferred a vehicle that was over $60,000. Currently many EVs available on the market are more expensive than their conventional vehicle counter parts, however in the next couple of years the price of EVs is expected to drop and more models will be available in the market place which will make more EVs available for the $20,000 to $40,000 price range. More SUV/Cross overs, trucks and vans will also be available in electric vehicle equivalents in the next few years.

When looking at the demographics associated with survey takers, some characteristics could be defined, shedding light on which demographic groups might be more influenced by incentives. For example:

- **Age:** Holding all other considerations constant (such as income and education), younger customers are more likely to purchase an EV. This relationship is stronger for BEVs than for PHEVs.
- **Income:** Higher income households are more likely to adopt a BEV. The effect of income on likelihood is not significant for PHEVs.
- **Political affiliation:** People identifying as Democrats are most likely to adopt an EV, with Republicans being the least likely.
- **Education:** Interest in an EV increases very consistently with education. This relationship is slightly stronger for PHEVs than for BEVs.
- **Prior ownership:** Prior ownership of a BEV increases the likelihood that the customer will purchase a BEV again in the future. However, prior EV ownership does not strongly influence likelihood to adopt a PHEV.
- **Prior exposure to an EV:** People who have ridden in an EV are more likely to purchase a BEV or a PHEV. This provides support for the possibility that "ride and drive" events would increase EV adoption.
- **Preference for vehicle type:** Customers seeking a passenger car are the most likely to adopt an EV, with those who are seeking a pickup truck being the least likely. This observation could partly be explained by the current lack of availability of electric trucks, as respondents potentially could have had difficulty expressing interest in a purely hypothetical vehicle type.

- **Population density:** People living in cities and towns (i.e., more densely populated areas) are more likely to adopt a BEV than those living in suburbs or rural areas.

The full dataset of survey responses was used to identify the impact that each incentive would have on customer segments varying by gender, political affiliation, previous EV experience, income, education, and location (i.e., city, town, suburb, or rural). The analysis estimates the percent increase in likelihood that the average customer in each segment would adopt an EV when each incentive is offered independently of the others General observations included:

- Women are significantly more receptive to offers of perks such as free parking, HOV access, and green electricity than men.
- Individuals identifying as Republican are more impacted by a majority of the incentives than non-Republicans in spite of having less interest in EVs overall.
- Incentives generally have a bigger impact on individuals without prior EV experience, possibly addressing proportionally greater range anxiety concerns from this segment.
- Individuals with higher incomes and education are more persuaded by the incentives.
- Free home charging stations are more appealing to individuals who live in cities, relative to rural or suburban areas.[1]

To estimate the impact of incentives, it was necessary to assume incentive values. In the case of the purchase price discount, a discount of $3,000 available at the time of purchase was assumed. For the home charging program, it was assumed that the Level 2 home charging station would be offered to customers at a cost of $1,000 (roughly a benefit of $500 dollars when the total price of a home charging station is assumed to be approximately $1,500). The electricity price discount for home charging is based on a 50% reduction on the retail rate. In this example the three incentives were started on different years and then continued until 2030. Fig. 2 shows the impact of these incentives above the baseline adoption projections.

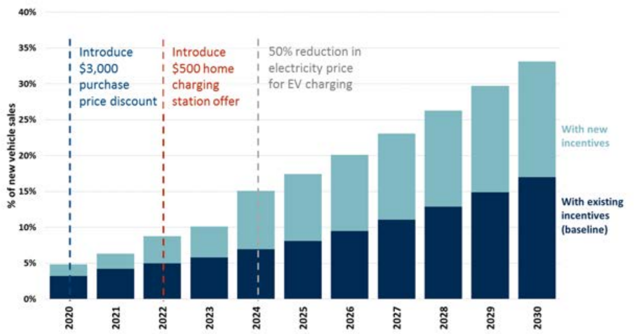

Fig. 2. EV share of new vehicle sales with incentive portfolio (national average). Note: Incentive impacts are based on analysis of survey responses from the eight participating utilities and are applied to a national baseline forecast of EV adoption. The analysis assumes each incentive is offered in isolation and does not account for any nonlinear impacts that may result from offering combinations of incentives.

Note that without any additional incentives other than the ones that are currently in place, EV sales continue to increase on their own however, the baseline sales are not high enough to achieve many state goals that help decarbonize the grid. By 2025, with these incentives in place, the % of new vehicle sales have more than doubled due to the presence of additional incentives, showing that incentives could drastically increase EV adoption.

When it comes to comparing the effectiveness of incentives, the cost of implementing each incentive needs to be calculated. Incentives such as purchase price reduction and reduction in electricity price, are easy to calculate, however the cost and benefits of some of the others are not as straight forward from both the utility and customer perspective. For example, the cost and benefits of increasing public charging station density can vary greatly. From the utility perspective, the chargers could be level 2 or DCFC which incur significantly different costs, sometimes an order or magnitude different. From the customer perspective, an increase in charging station density *could* be great if the charger has the correct connector, is in a place that the customer already frequents and offers electricity at a price that the customer finds appealing. However, if this charging station is in an inconvenient location, or the electricity doesn't meet the EV owners' price point, then it is something that they will not value as much and therefore it is harder to place an economic value on the charger. Each customer is faced with a unique set of circumstances and therefore will weight the value of an additional public charger differently.

B. *Utility Specific Results- Salt River Project*

As mentioned in the introduction, 8 utilities participated in the project. These utilities participated in the project to understand how incentives in and outside utility control may influence adoption in their service territories. It allows the utility to weigh the potential costs associated with each utility action and the effectiveness of the action on a regional basis thus allowing a calculation of $/EV added in their service territory. The following section highlights the regional analysis of one of the utilities in the study, Salt River Project (SRP), located in Phoenix, Arizona

Compared to the national average results, SRP customers have an average income similar to the sample average, a higher concentration of middle-aged customers and a lower proportion of 'high school graduate' and 'college degree' (24% vs 29% and 30% vs 34%, respectively). The following analysis highlights the variability of incentive effectiveness in SRP's service territory.

Incentives impact EV adoption with varying degrees of effectiveness depending on which incentive is applied and what level it is applied at. In order to assess the relative impacts of the incentive options considered in this study, a series of scenarios were modeled in which each new scenario included a single additional incentive. The sensitivity of the level of incentive is shown for four incentives, namely

[1] Urban/suburban/rural areas are defined as per the U.S. Census Bureau and are identified based on respondent zip codes.

purchase price discount, home charging incentive, electricity price discount, and increased density of public charging. As can be seen in Fig 3, Fig. 4, Fig. 5, and Fig.6, the relationship between the incentive and percent increase of new electric vehicle sales is not always linear. Note that these plots show additional adoption beyond the baseline adoption of 8.8% in 2025.

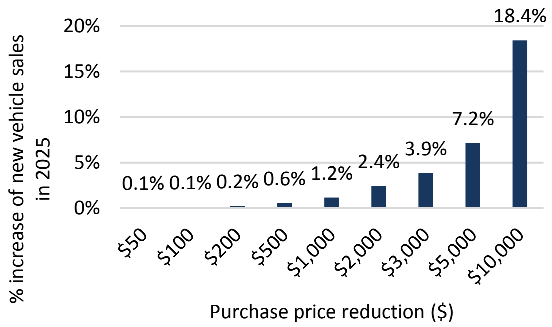

Fig. 3. % increase in new vehicle sales in 2025 due to different levels of purchase price reduction. These values are in addition to the baseline adoption in 2025.

Purchase price reduction shows significant adoption increases in 2025 at a price of $10,000 per vehicle purchased, however incentives at this level would probably be too cost prohibitive for a utility alone. However, incentives like this have occurred in the past like in the state of Georgia where a state incentive of $5,000 and a federal incentive of $7,500 dollars lead to a large amount of Nissan Leaf sales.

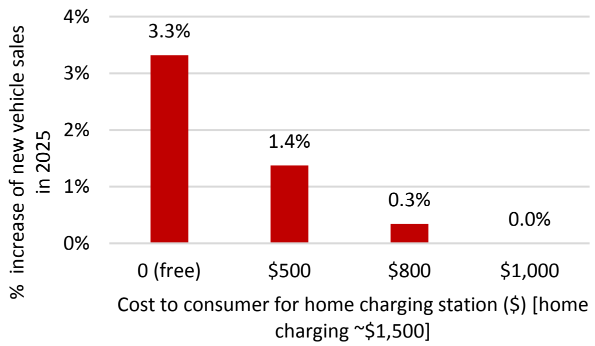

Fig. 4. % increase in new vehicle sales in 2025 due to different levels of home charging station incentives. These values are in addition to the baseline adoption in 2025. Note that even at a cost of $1,000 to the customer, the benefit is $500 dollars.

It is interesting to note that in the case of the home charging station incentive, even though the customer is still receiving a benefit of $500, the fact that they would have to pay $1,000 to receive the benefit negates any positive impact on electric vehicle adoption rates.

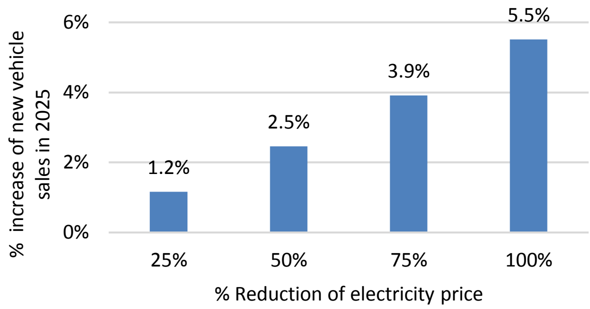

Fig. 5. % increase in new vehicle sales in 2025 due to different levels of electricity price reduction. These values are in addition to the baseline adoption in 2025. There is a potential to have these structured in a 'time of use' [TOU] rate which could potentially have additional grid benefits to the utility.

Offering a reduction in electricity price is a very appealing option for some utilities as it can also incentivize charging times through a time of use rate that, if effective, can provide grid benefits. A recent study that tracked 100 EVs over an 18 month period found that EV drivers were very responsive to TOU rate structures and almost exclusively charged during the cheaper hours [2, 3].

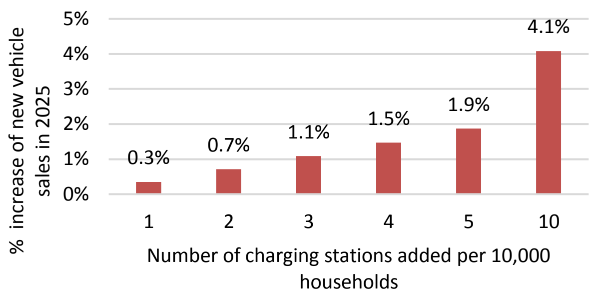

Fig. 6. % increase in new vehicle sales in 2025 due to added levels of public charging station density. These values are in addition to the baseline adoption in 2025. Note that these stations were defined to be based on a mix of chargers that could provide 20 miles of charge in anywhere from 10 minutes to 4 hours of charging time.

To look at the weigh the cost effectiveness of each incentive, where possible, incentives were chosen to show a similar benefit to customers. The EV projection model was then run to show how much these incentives would increase EV adoption in the year 2025 over the baseline adoption rate. All the incentives were applied from the year 2020 through to 2025. The incentives chosen were:

- Purchase price discount: $500
- Home charging station incentive: $500 customer benefit [home charging stations were estimated to be approximately $1,500 dollars, so in this case the customer would pay $1,000 dollars].
- Electricity price discount: 20% discount [over a 10 year life of the vehicle, assuming average charging rates, this equates to about $540 dollars of savings].
- Workplace charging: Available to all potential EV customers
- Green rate electricity option: Available to all potential EV customers

- High occupancy vehicle lane access: Available to all potential EV customers
- Free parking: Available to all potential EV owners
- Public charging station density increase: Charging stations were made available at a density of 3/10,000 households [these could be a mix of DC Fast charging stations or level 2 charging stations].

The increase in EV adoption to each of theses incentives in 2025 are shown in Fig. 7 and Fig 8. They have been divided into two sections, one is more cost tangible and the other weighs the non cash benefits of the action.

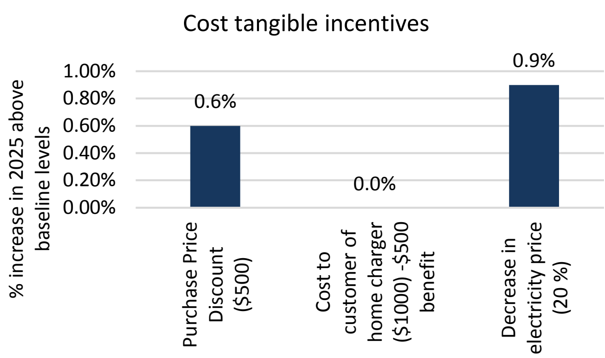

Fig. 7. % increase in new vehicle sales in 2025 of new vehicle sales above baseline adoption levels for cost tangible incentives

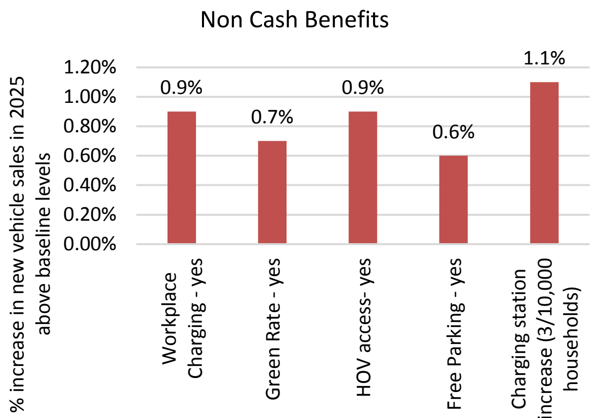

Fig. 8. % increase in new vehicle sales in 2025 of new vehicle sales above baseline adoption levels for cost tangible incentives

For the cost tangible benefits, a decrease in electricity price showed a larger increase in EV adoption in 2025 over the purchase price discount. The home charging incentive showed no increase in adoption. This is because potential EV customers don't view a payment of $1,000 a benefit, even though the charging station, on average, costs $1,500. The actual cost of implementing these incentives varies due to the number of customers they may apply to. For example, an electricity price discount may apply to not only new EV buyers but also to all past purchasers, a much larger pool than just the new EV buyers. However it must be noted that, if the electricity discount is only offered at certain hours and the utility benefits from a load shift, then there may be additional benefits to the utility that are not accounted for in this analysis.

For the vehicle purchase price discount, it would have to be available to those who would have purchased the EV anyway.

For the non cash benefits, the charging station increase showed the most promise over the others, however they were all similar in scale. Again, the cost required to implement each of these would vary depending on how they are implemented and who would incur the costs.

When all these incentives are combined together from the time period 2020 through to 2030, in 2025 they increase the % of new electric vehicle sales by 7.2% and 12.6% by 2030.

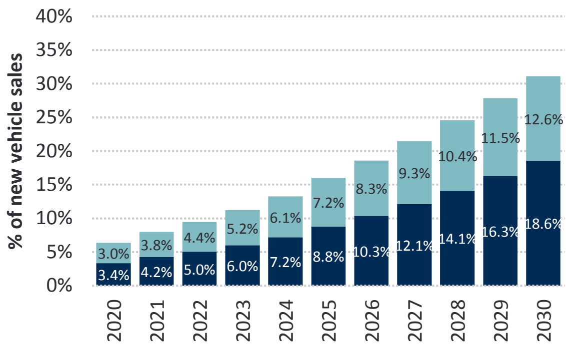

Fig. 9. EV share of bew vehicle sales with incentives. The dark percentages are the baseline adoption and the top (lighter color) percentages are the additional EV sales due to incentives outlined in Fig. 7 and Fig. 8.

A utility may choose to only implement one or two of these incentives, but this analysis shows what might be possible with an unlimited scope.

IV. Conculsions and Future Work

This analysis showed that incentives can be effective in helping increase EV adoption. It also shed light on which customer demographics might be more willing to consider an EV over other demographics. Due to the ability to ask customers about their willingness to purchase an electric vehicle that may not exist on the market yet (like an electric truck, or a cheaper electric van) the study results remain pertinent even as the market evolves to include these vehicles. With a decreasing price point, more models available and increased public charging infrastructure there will be more EV solutions available for customers in the next couple years.

This analysis focused on the new vehicle market however, the used EV market is a growing industry. A similar survey study would be useful to find the potential in the used EV market.

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