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EV Charging You Can't Refuse: Unlimited

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ABSTRACT

Utilities and their regulators recognize that growing electricity demand to charge electric vehicles (EVs) brings with it both opportunities and risks. Key opportunities exist such as the ability to absorb variable supplies of renewable energy, reduce wholesale energy market costs, and reduced automobile emissions. Risks include increases in demand during peak periods, increasing costs for utilities, grid capacity requirements, and carbon-intensive peaking generation. One successful strategy to increase benefits and mitigate risks is to influence the timing of EV charging through time-of-use (TOU) rates. This paper will summarize an impact evaluation of one utility's unique electric vehicle (EV) charging TOU program. The paper covers the program design background; a summary of the evaluation activities and approaches; and key findings.

Introduction

Program Background

In 2016, Austin Energy, a municipal utility, launched a unique EV charging incentive pilot program. Austin Energy had three main goals in launching this program. First, it wanted to avoid charging during peak periods. This would reduce usage when electricity is most expensive, would reduce Austin Energy's share of peak demand, for which it is charged annual transmission costs, reduce carbon emissions from fossil fuel-burning "peaker" plants, reduce the utility's exposure to price spikes in the ERCOT market, and reduce stress on grid infrastructure during peak periods. Second, Austin Energy wanted to align charging demand with renewable energy generation, which for Austin Energy, is available overnight through abundant West-Texas wind supplies. Third, Austin Energy wanted to create a program that would bolster customer satisfaction. Several utilities have initiated programs that aim to manage customer demand. (Feng 2019). The research this paper reports on builds on a similar methodology presented at IEPEC in 2019 completed for an east-coast investor-owned utility. This paper is intended to describe new results and an alternative program design.

While many utilities are piloting EV TOU charging rates, Austin's EV360 program is unique in its simplicity. Most utilities have provided discounts on off-peak kWh discounts at the whole-house meter and/or at the EV charger sub-meter. Instead of such variable rates, EV360 participants paid a flat per-month fee ($30 or $50 depending on charging load) to access unlimited charging during off-peak hours (7pm – 2pm on weekdays, anytime on weekends).[1] While EV360 participants are encouraged to charge during off-peak hours, they are also

[1] For EVs that have a max kW draw (at any time) of <10kW, the flat monthly subscription is $30 (in addition to whatever the customer is billed for charging during the on peak periods). For makes and models of EVs that have a max kW draw (at any time) of 10kW or greater, the flat monthly fee is $50 (in addition to whatever the customer is billed for charging during the on peak periods).

discouraged to charge during peak hours. EV360 participants are charged an additional $0.40/kWh for EV peak charging in the summer and $0.14/kWh for peak EV charging in the winter while charging in their homes. They, therefore, were required to install separate EV charging metering equipment at their homes.[2] Finally, participants have unlimited access to a network of public charging stations around their service area for which they have unlimited charging at any time that is not subject to time of use rates. Table 1 provides a summary of the EV charging rate details for EV360 participants. This paper only covers analysis of at-home charging, however it will be important to study temporal load impacts of public charging data in a future study to complement this research.

Table 1. Details of EV Subscription Schedule for in home charging.

Charging Type	Time Period	Cost to Charge (Summer)	Cost to Charge (Winter)
Paid Charing (On-Peak)	2:00 p.m..-7:00 p.m.	$0.40/kWh	$0.14/kWh
Unlimited Charging (Off-Peak)	7:00 p.m.-2:00 p.m..	$0.00/kWh	$0.00/kWh

Figure 1 and Figure 2 display the peak and off-peak pricing details for EV360 participants in summer peak and off peak months respectively. Note that Austin Energy's base residential energy rates are tiered based on the magnitude of consumption. In the figures below, the whole-house residential $/kWh is an estimate that blends all per-kWh charges and assumes a home that consumes 1,000 kWh monthly. The relatively high on-peak EV charging costs are tied only to the sub-metered EV charging station, and are designed to significantly disincentivize customers from charging at this these times.

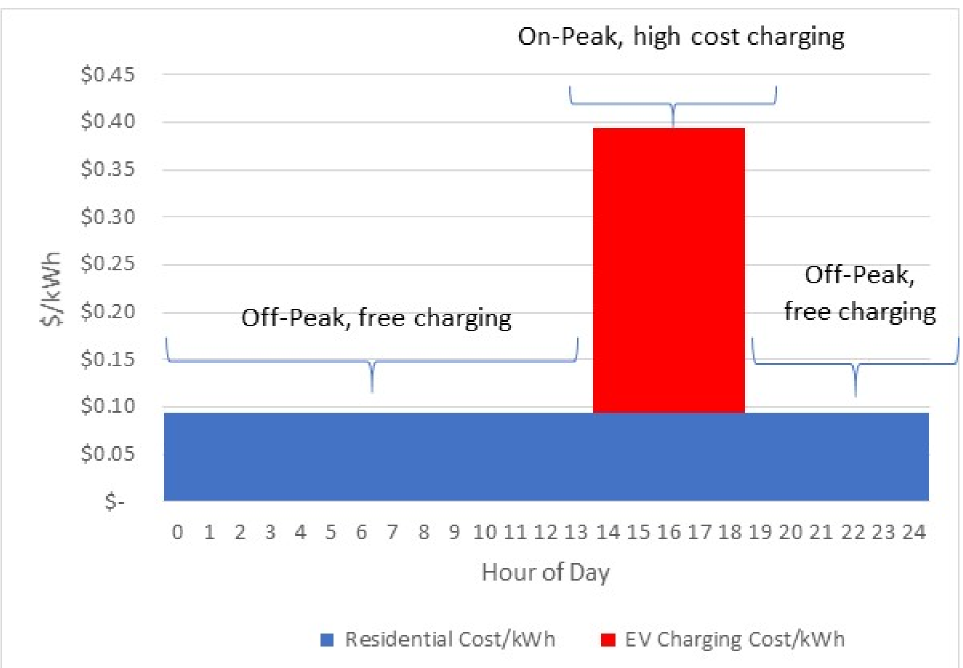

Figure 1. Details of EV360 for June 1 through September 30

[2] Note that Austin Energy provides the sub-meter and the customer pays for the sub meter circuit coming from the electric vehicle supply equipment (EVSE).

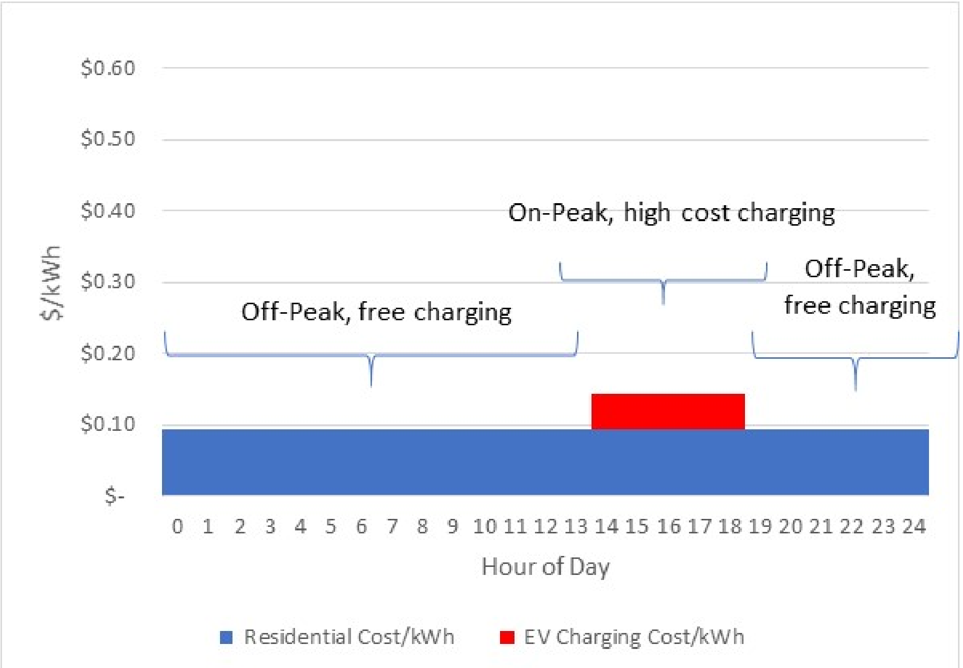

Figure 2. Details of EV360 for October 1 through May 31

At present, Austin Energy estimates that they have around 11,000 battery electric vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) actively charging and driving within their territory. Austin Energy accepted approximately 90 people in the pilot program. While initial signups were slow, participation accelerated with increased marketing. Through surveys, participants have given an average overall satisfaction rating of 9/10, indicating that the program improves the overall Austin Energy customer experience.

Scope of Evaluation

The evaluation team studied the extent to which these rate plans influenced customers to charge their EVs during system off-peak hours (between 7:00 PM to 2:00 PM). The pilot program was initially designed to be promoted until it reached or came close to reaching the participation cap of 100 participants. Due to the program's popularity and success in curtailing peak-time charging, it is being extended and possibly enhanced with other options and features. The evaluation research objectives were to:

- Obtain interval load profiles including
    - Sub-metered home charging stations for EV360 participants (August 2019)
    - Whole-house consumption for EV360 participants after subscribing to the EV360 program (August 2019)
    - Whole-house consumption for EV360 participants before participation in the EV360 program (August 2016)
- Determine whether the program significantly time shifted charging behavior as well as reduced EV charging peak demand and overall difference in magnitude of demand between program participants before and after the introduction of free off-peak charging.

Methodology

Data Processing

As the first EV charging sub-meter was activated in September, 2016, the evaluation first defined a consistent pre-EV360 participation period (August 2016) and a post EV360 participation period (August 2019). Second, evaluators separated participants into two cohorts: Cohort 1 included customers who reported owning EV's during the pre-period and Cohort 2 included customers who reported not owning EV's during the pre-period. Researchers then isolated post-period sub-metered charging station interval data for both groups and whole-house meter pre-period data for both groups. Researchers thus removed customers who did not report owning or not owning EV's in 2016 from this analysis. In addition, evaluators performed extensive validations and range and consistency checks on the interval data to detect and control for gaps and anomalies. Researchers performed monthly checks to start, and annual checks after participant summer data were delivered. Through these efforts, researchers ultimately limited the evaluated sample to 30 customers out of 89 total participants, a resulting dataset that is admittedly small. We therefore decided that there was an opportunity to consider unique premise-level insights. Indeed, given the small size of this pilot, individual charging decisions bring substantial insights of their own. This approach attributed differences in the usage patterns, such as shifts in peak load, to program impacts (i.e., incentivized behavioral changes resulting from the EV360 pricing schedules).

Table 2 presents the participant count for each of the participant and comparison groups.

Table 2. Summary of Analysis Data Set

Customer Group[1]	Number of Customers
Cohort 1: EV Pre-Period (August 2016) and EV360 Post-Period (August 2019)	9
Cohort 2: No EV Pre-Period (August 2016) and EV360 Post-Period (August 2019)	21
Total Evaluated Sample Size	**30**
Total EV360 Population as of August 2019	**89**

[1]Note that reporting EV purchase date was voluntary for EV360 participants and many did not report this data, limiting our ability to include customers in either group

Analysis

Time of Use Comparison

Researchers used interval load data to generate average hourly program load shapes as part of its evaluation, measurement, and verification (EM&V) approach. The impact evaluation involved direct metering and modeling (measurement) of program impacts by considering the average hourly interval load shapes of program participant as well as the whole-house interval load shape of the same participants. This study considered three specific analyses:

1. **Cohort 1: EV360 Sub-Metered Charging Consumption, Post-Period Analysis Only.** For customers who owned an EV in 2016 and had signed up for EV 360 by 2019 (Cohort 1), we calculated their overall average sub-metered home charging load shapes. These customers had established charging behaviors and may have been more difficult to convert to off-peak chargers.
2. **Cohort 1: EV Pre-Period and EV360 Post-Period.** Again for Cohort 1, we compared the difference between 2016 whole-house load and 2019 whole-house load including EV charging. This comparison revealed overall impacts including changes to household consumption.

3. **Cohort 2: No EV Pre-Period and EV360 Post-Period.** For Cohort 2, customers who did not own an EV in 2016 but had signed up for EV360 by 2019, we again compared the difference between 2016 whole-house load and 2019 whole-house load including EV charging. We compared these customers separately from those who owned an EV in the pre-period because any 2019 EV load is additive, not shifted.

Table 3 summarizes these three analyses as they relate to the two evaluated groups and the data that each analysis used. The numbers presented in this table represent the bulleted number associated with each analysis above.

Table 3. Summary of Analyses by Cohort, Data Type, and Data Period

Cohort	**Data Type**	**Pre-Period (August 2016)**	**Post-Period (August 2019)**
Cohort 1: Participants with EV During Pre-Period	Charging Submeter	NA	1
	Whole House Meter	2	2
Cohort 2: Participants with EV During Pre-Period	Whole House Meter	3	3

Survey and ESRI Tapestry

Austin Energy conducted online surveys with pilot participants in July 2019 and used ESRI's Tapestry platform, a GIS-based customer segmentation tool, to expand our understanding of participant groups (ESRI, 2019). The purpose of the surveys was to inform the following research objectives:

1. Verify EV make and model, charging equipment make and model, vehicle purchase date, household characteristics, participant satisfaction, and driving habits.
2. Confirm the respondent is enrolled in either pilot rate schedule.
3. Identify changes in charging habits due to enrollment in an EV360 Pilot Program
4. Determine the respondent's satisfaction with his/her participation in EV360.
5. Determine opportunities for program design improvement through questions that ask what went well with program design, and what could be improved.
6. Identify which Tapestry segmentations program participants fit within.

Results

EV360 Sub-Metered Charging Consumption

Figure 3 shows the average August 2019 hourly load shape based on sub-metered charging data for the 9 EV360 participants who reported owning EVs during the pre-period. The graph shows a sharp spike in demand (or charging) for these customers during free-charging period between 7:00 PM – 2:00 PM.

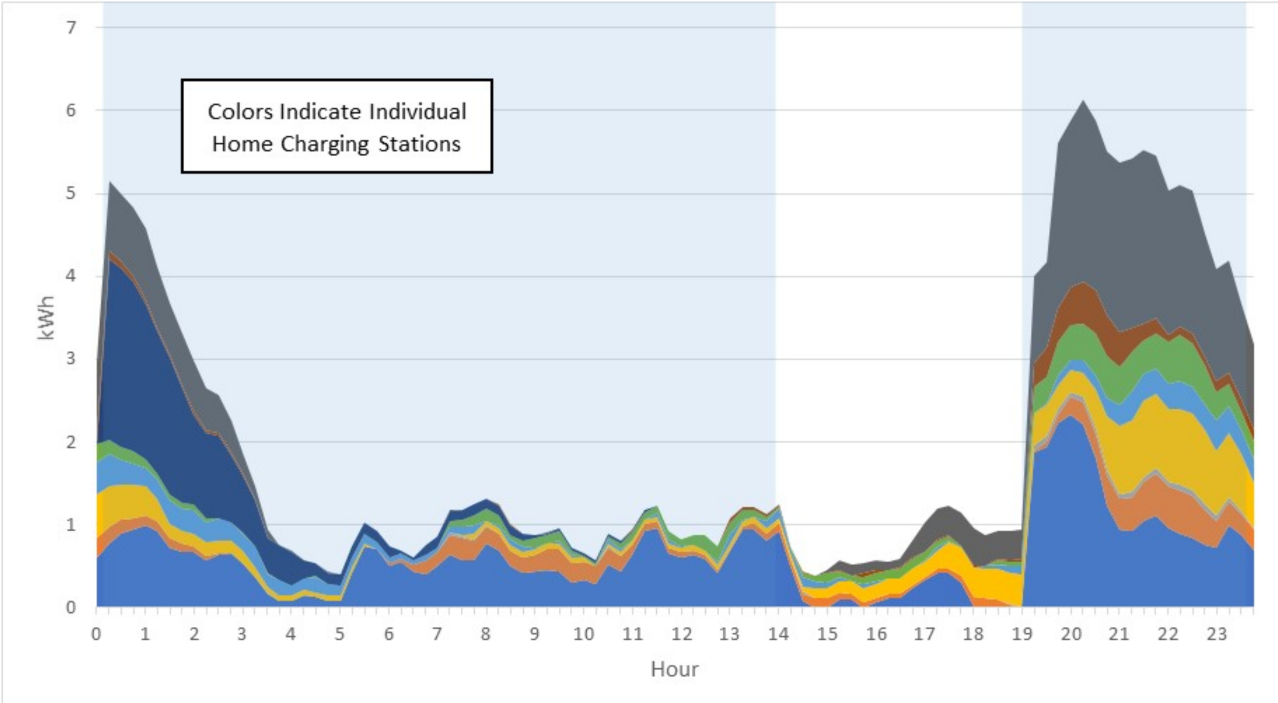

Figure 3. Cohort 1 August 2019 Sub-Metered Charging Load Profile (n=9)

The difference between off-peak and peak charging is dramatic for this cohort. Most notably, charging appears to start directly at 7:00 PM and taper off towards midnight. Another spike appears to arise just after midnight. Looking at the specific load shapes, one customer in particular has set charging to begin at midnight while the remaining customers set charging to begin immediately at 7. Researchers do not have insights into the specific drivers or mechanics behind these charging behaviors. However, EVs are technically designed to allow customers to set automated charging schedules. There is variability among participants who only need a top-off charge and others who require significant charging. While 4:00 AM -2:00 PM remains free charging within the program, there is very little (though some) charging occurring. The minimum average charging load is observed starting at 2:00 PM which matches the program design and intent. Several customers do appear to charge a minimal amount between 3:00 and 7:00. Still, all 9 customers charged less than 1 kWh per hour during peak times, compared to an average of 1 kWh - 5 kWh per hour starting immediately at 7:00 PM, making it clear that the program has been very successful in shaping customer charging behavior among these participants. If anything, rate designers may eventually want to consider staggering the start time for charging to avoid an unintended shock to the grid as EV ownership and program participation grow. Given that these customers owned EV's prior to the program and had begun to develop charging behaviors, it is notable that the program has successfully shifted those behaviors.

EV Pre-Period and EV360 Post-Period

Figure 4 shows Cohort 1's average hourly load profile for the post-period (green line) and pre-period (blue line) for the month of August. The graph shows that the peak demand occurs both at 4:00 PM and 1:00 AM for the pre-period and at 7:00 PM and at 1:00 AM during the post period. While Figure 3 above only includes EV charging load, the loads shown here include all household usage; thus the higher pre-period usage from 4:00 PM through 7:00 PM may represent energy usage from other appliances in the home which were not measured or seen in the results from the post-period measurements.

Figure 4.Cohort 1 August 2016 and August 2019 Whole-House Consumption (n=9)

The difference in the average hourly consumption between the pre- and post-periods is close to zero around 10:00 AM to 1:00 PM (when usage is most similar). This suggests that beyond the EV usage, customers did not significantly change their electricity consumption.

No EV Pre-Period and EV360 Post-Period

Figure 5 shows Cohort 2's average 2016 (blue line) and August 2019 (green line) hourly whole house load profile. The graph shows that the peak demand with EVs occurs period between 7:00 PM and 9:00 PM at a magnitude of 1.8 kWh. For the same customers, prior to EV ownership, peak demand occurred between 4:00 PM and 7:00 PM at a magnitude of around 1.1 kWh. For these customers, post-period demand from 7:00 PM through 12:00 AM accounted for 33.3% of average daily electricity use.

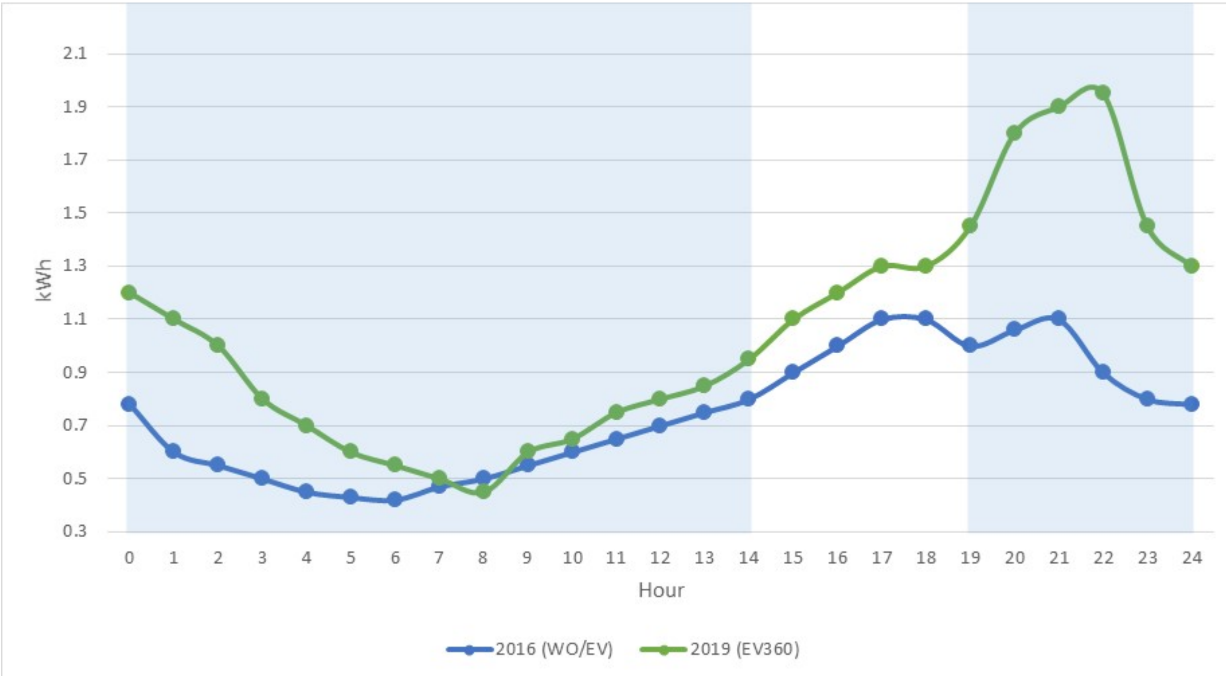

Figure 5. Cohort 2 August 2016 and August 2019 Whole-House Consumption (n=21)

The difference in the average hourly 2019 consumption and hourly 2016 consumption (before these customers purchased an) EV is close to zero from 8:00 AM to 2:00 PM, indicating similar usages during this time. Note that the slight increase in 2019 data from 10:00 AM to roughly 5 PM is most likely due in part to the unseasonably hot month of August in 2019. We suggest future research weather-normalize these comparisons to net out such effects. Nevertheless, this comparison reveals the very clear indication that vehicle charging increase loads noticeably between midnight and 6:00 AM and dramatically from 7:00 PM to midnight.

For both groups – EV360 customers who owned EVs before the program and those who did not, this program has demonstrated consistent success in incentivizing participants to charge during off-peak hours. The vast majority of the charging load hits at the start of the free-charging period. We note that these customers are make up a relatively small sample, and that they are likely early adopters. Still, this finding suggests that Austin Energy has developed a strong-enough price signal to influence customer behavior for this group of customers. Moving forward, Austin Energy will continue to monitor charging load shapes as the program expands to more customers and EV adoption continues to increase.

Survey Results

Perhaps not surprisingly, given the remaining high cost of EVs at the time of this study, EV adopters continue to be largely well-educated (a characteristic often highly correlated with income). Approximately half of the EV360 Tapestry study population (91 participants total) were included in this study. This sample of customers fit in the following segments, listed in descending order: 1A Top Tier , 1C Boomburbs, 1B Professional Pride, 8B Emerald City (ESRI 2019).[3] In a similar study conducted by the Smart Energy Consumer Collaborative (SECC) that surveyed a representative sample of residential energy consumers across the US, 31% of respondents overall believed their next vehicle purchase would be an EV if it were the same price as a gas-fueled vehicle, compared to 51% of so-called "Green Innovators" and 41% of so-called "Tech-Savvy Proteges" (SECC, 2020). In

[3] Note that the Tapestry study occurred when the pilot program had 91 participants and the EV360 pilot as of August, 2019 only had 89 participants due to two customers dropping out of the program.

2016, very high interest in EV adoption among the general public was around 20%, showing that in the past four years, there has been a 50% increase in serious interest in adoption EVs (SGCC 2016).

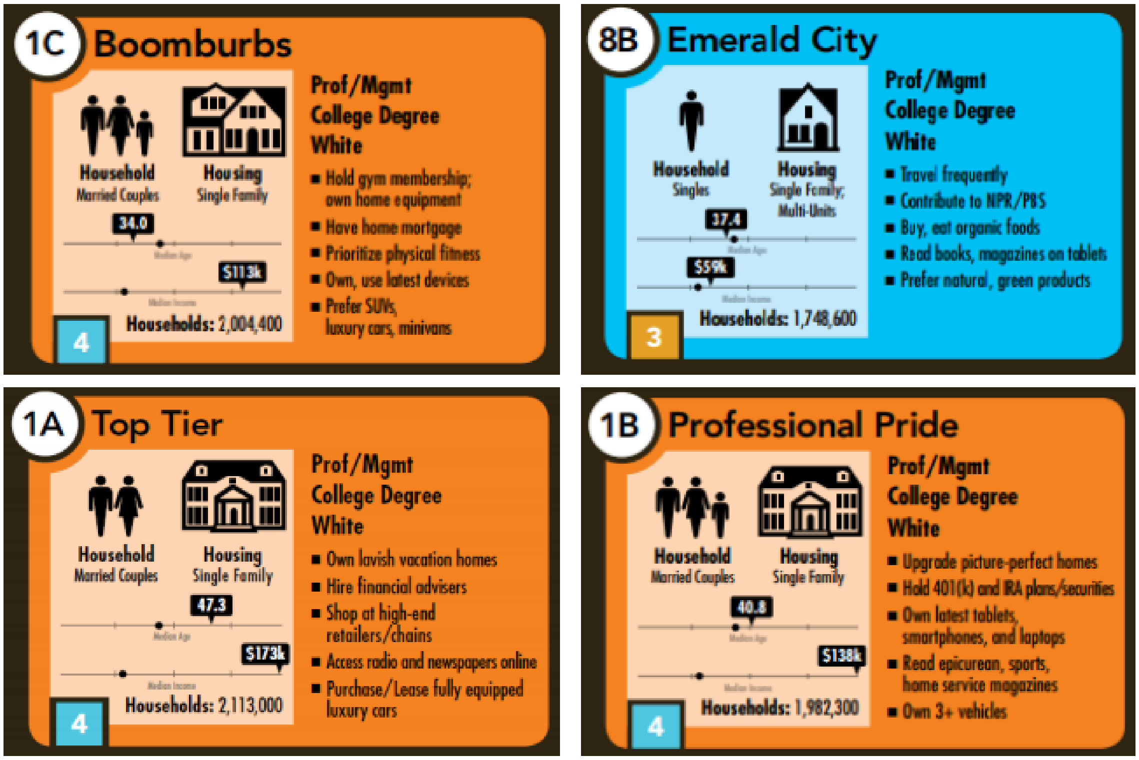

Figure 6. The ESRI Tapestry Segments that Represent the Majority of EV360 Participants

Tesla was the manufacturer of 40% of the participant group vehicles, as illustrated in Figure 6. The next two most popular manufacturers among all respondents were Chevrolet and Nissan.

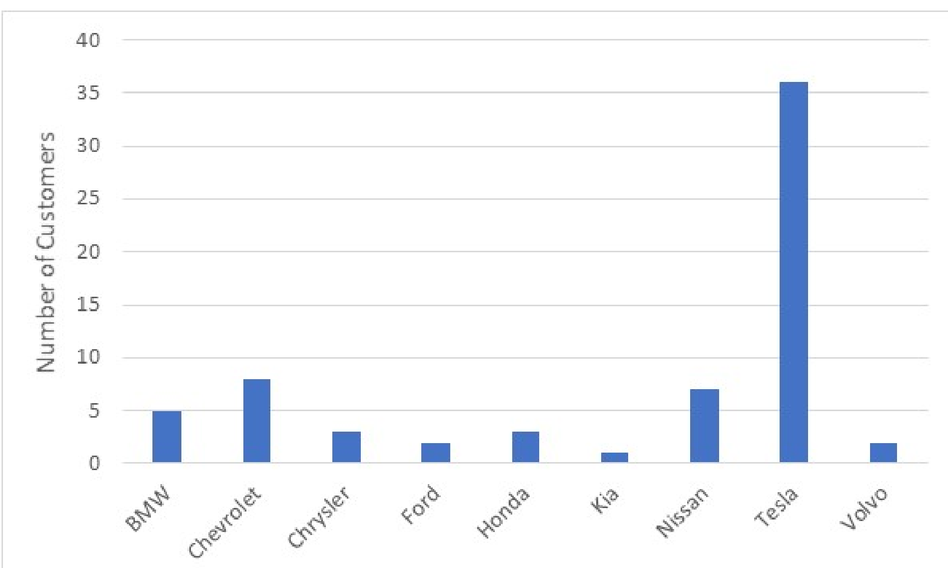

Figure 7. Types of Vehicles (n=67)

The survey suggests that the program remains exceptionally popular for participants as shown in Figure 8. Overall, participants were very satisfied with the EV360 rate. When asked on the survey, 83% of customers rated the program very highly (8 or greater), with 63% giving the program a 10 out of 10.

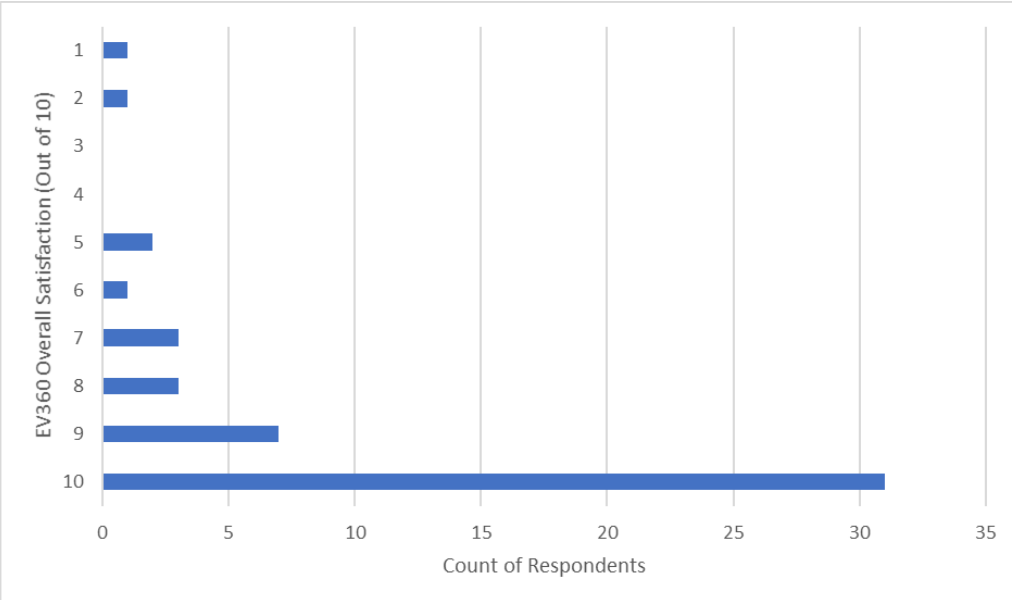

Figure 8. Program Satisfaction Ratings of EV360 Participants (n=49)

Figure 9 shows that participants are favoring all-electric battery electric vehicles (BEVs) over Plug-in Hybrid Electric Vehicles (PHEVs). 75% of vehicles were BEVs while 25% were PHEVs. Recall that Tesla's account for 40% of EVs; therefore, the 35% of EV's are non-Tesla BEVs and 25% are PHEVs.

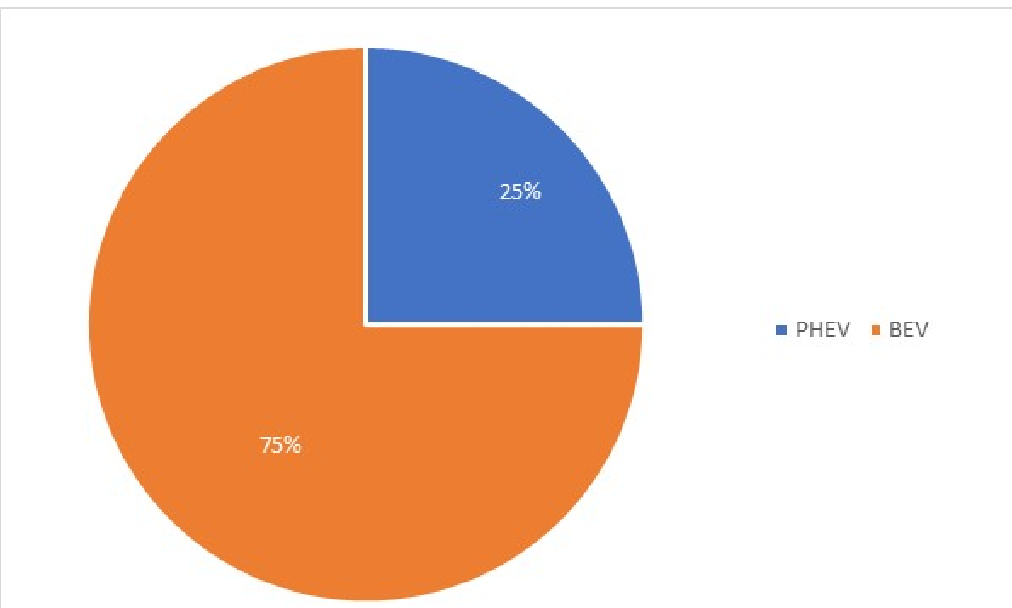

Figure 9. BEV vs PHEV adoption among Participants

Conclusions

EV adoption continues to rise in Austin Energy's territory and transportation electrification makes up a large part of Austin's city goals. As Figure 9 indicates below, battery electric vehicles have continued to account for over 50% of EVs since 2013 and currently account for roughly 75% of EVs. Adoption is expected to continue to rise. This research has suggested that Austin Energy has developed a popular and effective approach to managing charging demand.

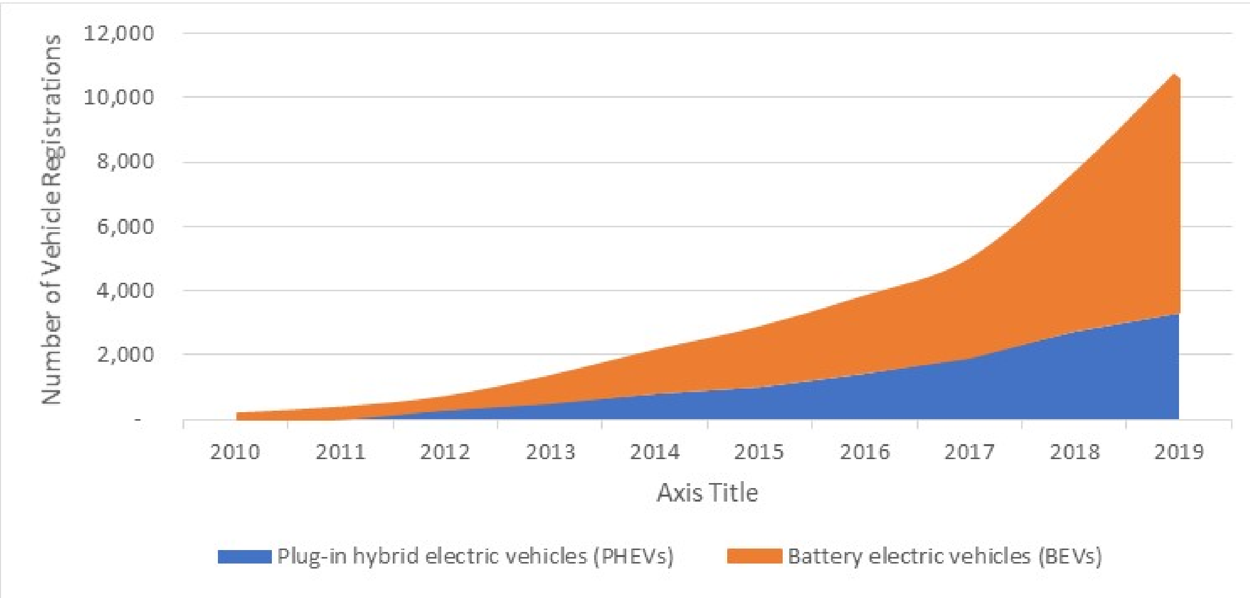

Figure 10. Current Levels of All-Electric and Hybrid Vehicle in Austin Energy Territory and Surrounding Counties from 2010 through 2019.

There are continued advancements in EV and charger manufacturing, financing, installation, and adoption. Many major vehicle manufacturers have made significant commitments to offer EV models in the near future. In 2018, Ford announced an $11 billion investment in new battery-electric and hybrid gasoline-electric models (Lienert 2018). General Motors outlined plans to introduce 20 new battery and fuel cell EVs by 2023. Volkswagen AG plans to spend $40 billion by 2030 to build electrified versions of its more than 300 global models (Lienert 2018). In their 2019 EV Outlook, the International Energy Agency estimated that EV's will make up 8% of vehicle sales in the US under their "New Policy" scenario and up to 30% of vehicle sales in the US under their EV-accelerated scenario "EV30@30." (IEA 2019).

The results from this load shape study and corresponding customer survey offer Austin Energy early feedback on how to respond to that growth. It is clear from early results that Austin Energy has developed a successful approach to manage EV charging demand. The changes in consumption are dramatic. The magnitudes of EV charging at 7:00 PM, the beginning of the unlimited charging period, are clearly notable when compared to the remaining whole-house consumption.

While it is clear that the rate has successfully incentivized customer charging behaviors, additional research can help develop essential insight. Importantly, the risk of an overly-successful program, in coincidence with an increase in EV demand and EV360 rate participation has the potential to create a double peak for these customers and incur rapid ramping requirements. Such impacts have been identified by a similar study in San Diego Gas and Electric territory (Kim, 2019). In addition, we look forward to weather-normalizing the whole-house data to remove heating and cooling loads and effectively compare baseloads within which we expect to see EV charging, compare larger groups to EV drivers on no-EV rates, and other comparisons not covered here.

We also believe that developing a clustering approach will be especially important when the EV360 population grows substantially. By creating charging clusters, we will be able create average load shapes with tight confidence intervals. Additional cost-effectiveness research will help to optimize the cost of the subscription.

While many utilities are exploring off-peak discounts to shift load, Austin Energy's unlimited charging approach is novel. The rate is seen by participants as incredibly popular and effective at managing behavior. Furthermore, their program maintains complete flexibility and scalability. As ERCOT prices evolve, as solar adoption continues to increase and the peak period shifts, Austin can modify the unlimited charging period accordingly. In striking the balance between those two goals, Austin Energy is uniquely positioned to welcome the increasing EV demand within their territory while improving their impacts on system load to better align with the needs of the grid.

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