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Lessons from In-Use Fast Charging Data: Why Are Drivers Staying Close to Home?

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Abstract

By examining a large in-use dataset from the charging provider EVgo, we study the relationship between home and fast charging. Many consumers are charging close to home with more than half of the paid sessions being less than 10.3 miles as the crow flies and 13.6 miles network distance from home. Free sessions (2 years of unlimited charging provided by the OEM at the time of vehicle purchase) are 4.9 miles from home as the crow flies. Further, increased usage in the early morning for free fast charging indicates the same trend where consumers may delay home charging in order to fast charge or simply do not have access to a home charger. These results, consisting of over 95% Nissan LEAFs, suggest that fast charging is being used as a substitute for home or other public charging in some cases. Further research is needed to determine whether these trends will continue with longer range BEVs.

Introduction

There have been several modeling attempts to describe the potential uses for fast charging [1-5]. These modeling exercises usually depend on an assumed charging behavior coupled with an external travel dataset. Most of the models assume a user has access to charging at home and that the user charges to 100% on those days when range is required. This implies that the fast charger is the charger of last resort and level 1 120V charging (L1) or level 2 200+V charging (L2) will be used if available. Our research uses actual charging station data to investigate these assumptions and glean insights into how drivers are using fast charging stations.

Background

Modelling fast charging has been done looking at the travel behavior of gasoline vehicles in a variety of ways from a small number of GPS tracked vehicles [1] to larger travel diary datasets from a statewide survey in California [2-5]. These models focus on locating fast chargers at the point where a battery electric vehicle (BEV) would run out of charge and detailing how many would be needed to serve all travel. This has been called "corridor demand" by some modelers [5]. Ji et al [5] incorporates driver fatigue such that the likelihood of using a BEV declines if travel requires more than one fast charge to complete travel using survey results from Nicholas et al.[2]. Some studies [6, 7] use home and work as likely locations coincident with demand to model fast charging demand. However, how well do these models reflect current fast charger usage? Are home and work likely locations coincident with fast charging or does usage correlate with when the battery runs out? Some studies suggest that drivers of BEVs are unlikely to drive past the one-way range of their vehicle such than an 80 mile BEV will seldom if ever be found 80 miles from home over its lifetime [8]. How often does this happen based on usage data? We examine usage data from charger transactions from EVgo fast chargers and a survey of users taken at fast charging sites.

Data Description

We examine 1,038,799 fast charging sessions from EVgo of which 807,969 have distance from home in both Euclidean and road network distance provided. The events are from January 2014 to October 2016. The data include price paid per transaction, energy in kWh, and start and end times for all events. The users of the stations are 95% or more Nissan LEAFs. Specific models are only user reported, so exact numbers are not possible.

Data Exploration

To explore how drivers are using fast charging and provide a first look at how we may model fast charging usage in the future we compare distance from home to fast charger to two studies (Figure 1). One study surveys where people would place fast chargers for their Nissan LEAF [3] labeled “Desired DC Fast”. The next study is the modeled needs of fast chargers for BEV 80s assuming customers charge based on when they run out of charge [5].

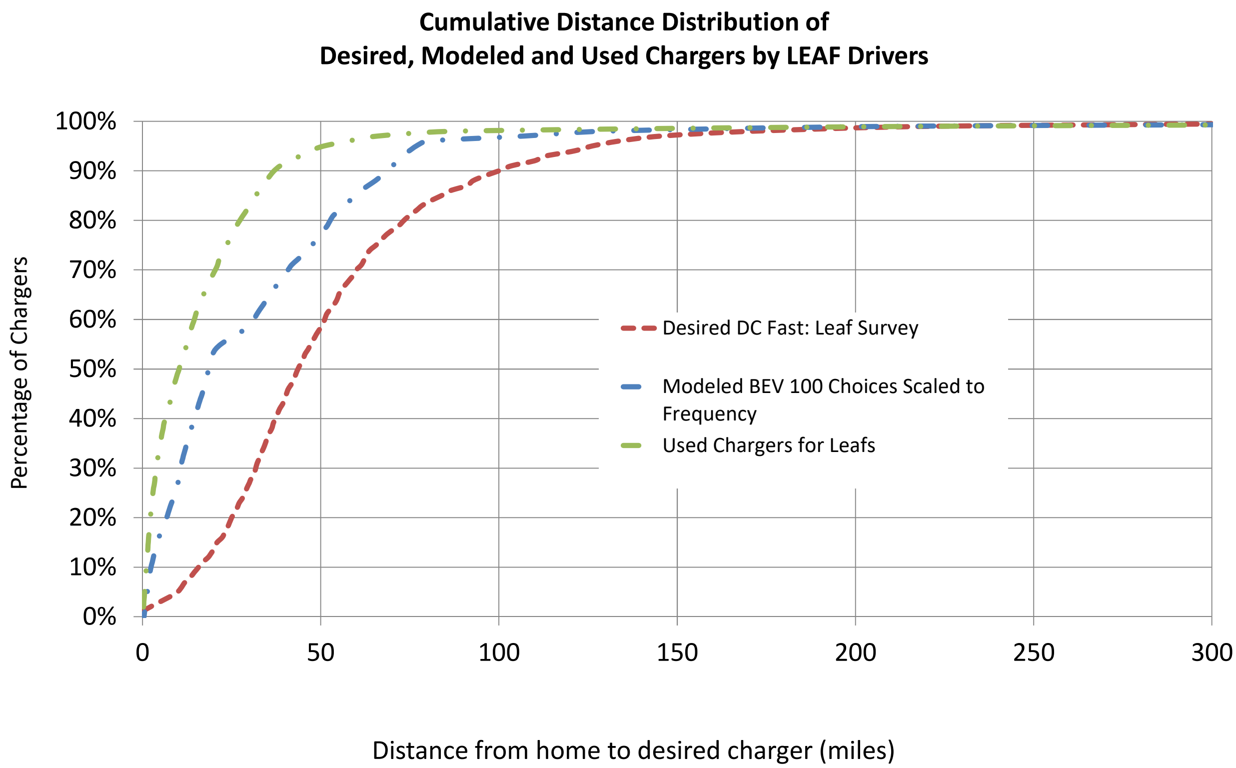
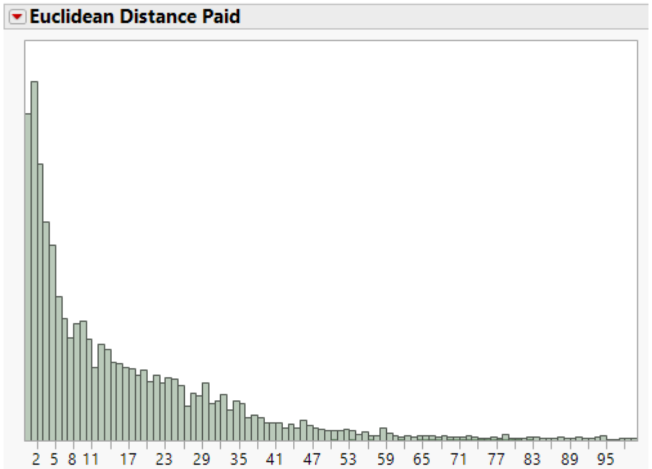


Figure 1 Comparison of the distance from home of used, modeled and desired fast chargers

When asked to place desired fast chargers independent of usage (Desired), sites selected by LEAF drivers had a median distance from home to desired charger of 44 miles. When modeling usage of where LEAF drivers would run out based on normal trip distribution (Modeled), the median distance from home weighted to need was 18.5 miles. However, when paid charging sessions of 10 cents a minute (plus a $14.95 monthly subscription fee) were analyzed, the actual median distance from home was only 10.2 miles, meaning that even when a customer is paying for charging, 50% of charging events are less than 10.3 miles from home (Figure 2). All distances are as the crow flies or Euclidean. When compared to network distance, the same distance for paid events was 13.6 versus 10.3, an increase of 32%.



Quantiles

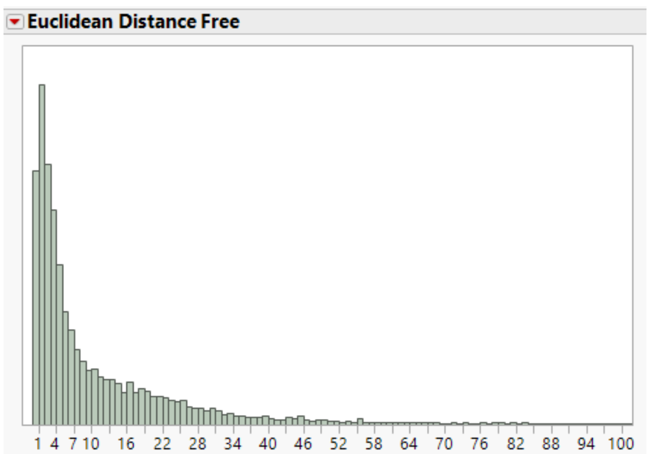
100.0%	maximum	599.279
99.5%		375.823
97.5%		89.42
90.0%		39.109
75.0%	quartile	23.841
50.0%	median	10.288
25.0%	quartile	3.135
10.0%		1.238
2.5%		0.327
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	20.532965
Std Dev	43.042153
Std Err Mean	0.1018049
Upper 95% Mean	20.7325
Lower 95% Mean	20.33343
N	178752

Figure 2 Distance from home in miles for paid fast charging

Free events (Figure 3) were even closer to home at a median distance of 4.9 miles from home with a network median distance of 6.8 miles.



Quantiles

100.0%	maximum	597.652
99.5%		91.0065
97.5%		48.58875
90.0%		26.542
75.0%	quartile	14.15
50.0%	median	4.911
25.0%	quartile	2.044
10.0%		0.96
2.5%		0.362
0.5%		0.109
0.0%	minimum	0

Summary Statistics

Mean	11.368848
Std Dev	23.855353
Std Err Mean	0.0322581
Upper 95% Mean	11.432072
Lower 95% Mean	11.305623
N	546884

Figure 3 Distance from home in miles for free (with the purchase of a vehicle) fast charging

Since fast charging is used closer to home than predicted by modeling [9] or surveys [3] we can postulate several hypotheses. First, reliability may be a perceived issue. Early fast chargers with various brands and host site situations were not numerous and some had maintenance and reliability issues. This possibly affected the perception of being able to charge when arriving at a station. Second, most households have a gasoline vehicle in their fleet in addition to the BEV with no range limitation and are preferred for long distance trips [8]. Third, fast chargers are useful as backup for level 2 and we should expect close-to-home fast charging to be the dominant paradigm. Finally, customers may be using fast charging in lieu of home charging when it is not available. This may be even more likely if charging is free for 2 years, bringing new users into the market near a fast charger.

When fast charging is free it is more likely to be used as a substitute for home charging than when it is paid. Evidence for this is shown in the start time of free charging (Figure 4) versus paid charging (Figure 5).

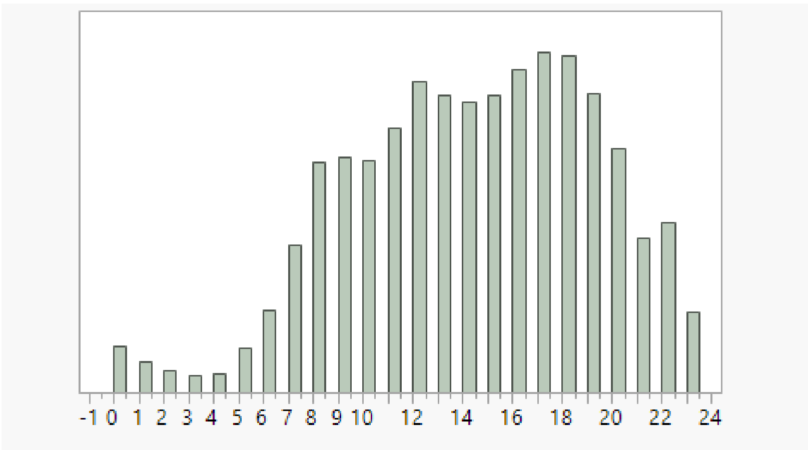


Figure 4 Start Hour of free (part of the vehicle price) fast charging

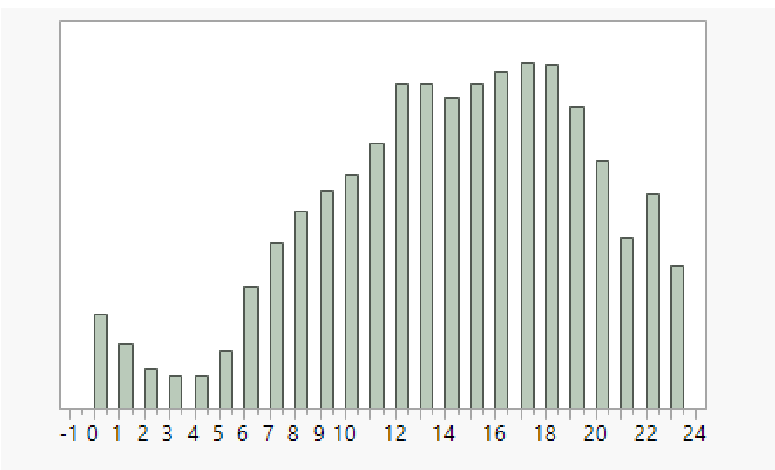


Figure 5 Start hour of paid fast charging

A morning peak is present in the free charging data, but absent in the paid charging data. Presumably this group charging in the morning are switching home charging to fast charging, or they do not have home charging. The time periods are also instructive. In both the free and paid charging data we see a lunch time and early evening peak. This suggests a usage pattern associated with workplace or eating activities.

We can compare this to modeled fast charging times such as those represented by UC Davis modeling shown in Figures 6-8. The modeling is based on gasoline vehicle trips from 40,000+ households in the California Household Travel Survey (CHTS) and one day of driving for all household vehicles. The scenarios below are for BEV80 vehicles. Figure 6 represents modeled demand for fast charging on home based trips. The temporal demand represents the time of the first trip of the day by a vehicle.

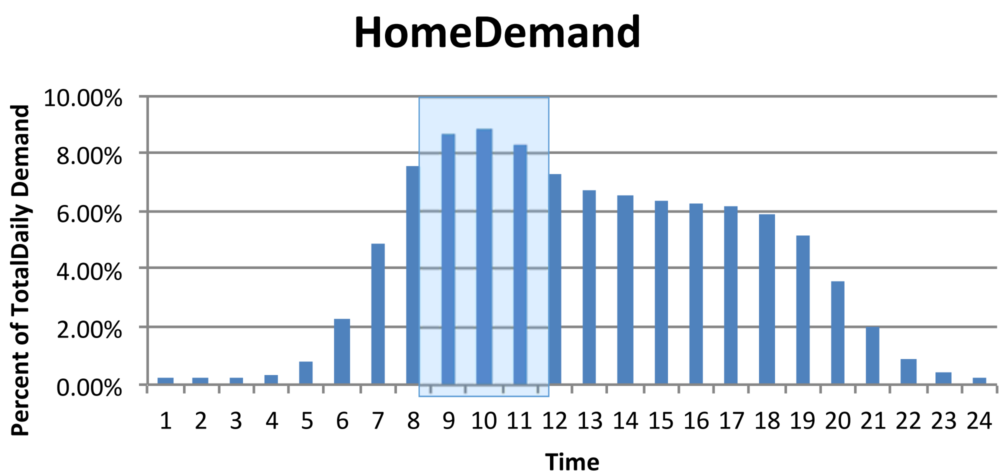


Figure 6 Modeled temporal demand of charging on trips that originated from the home

The timing for workplace demand is determined by those who use their vehicle midday then return to the office and when people leave work for home. The temporal pattern of workplace demand represents those who need level 2 in order to return home with a range buffer of 10 miles. The modeling does not assume this is a daily occurance, but would be a backup for level 2 if it is congested. If charging is needed at work, there are two chances to charge, durring lunch and before the commute home.

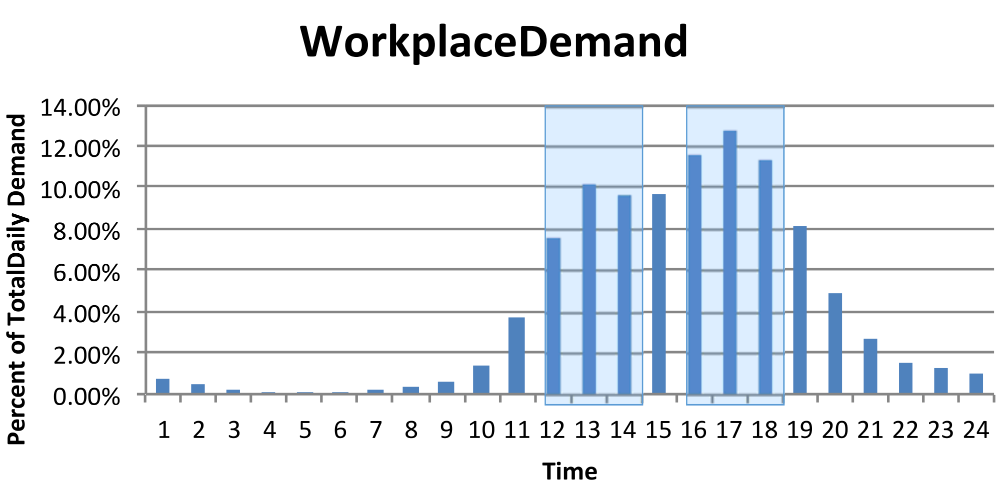


Figure 7 Modeled Demand of charging on trips that originated from the workplace

Corridor demand (Figure 8) is simply the time of day that a BEV if charged to 100% at home would have traveled at least 64 miles (20% reserve of 16 miles), based on travel diary datasets from a statewide survey in California.

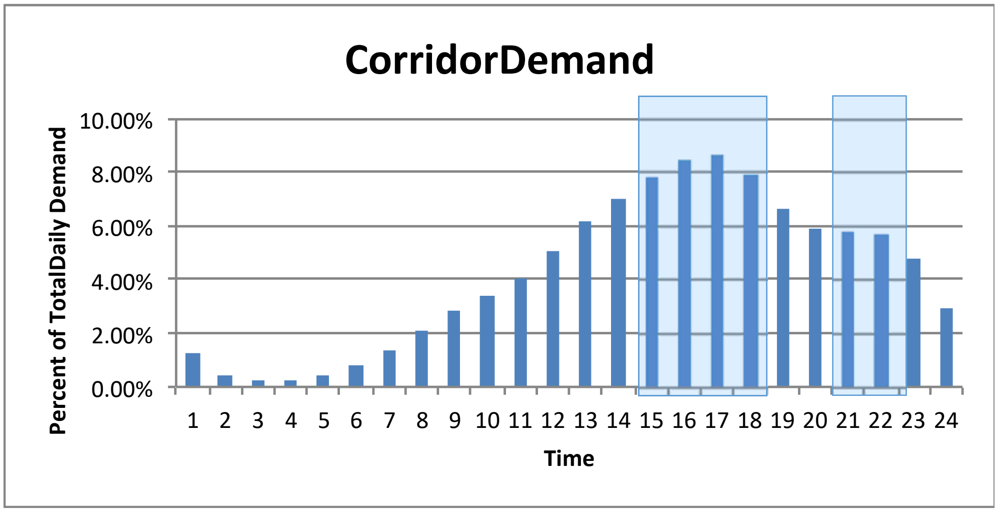


Figure 8 Modeled demand of when drivers would run out of charge, using CHTS data on gasoline vehicle patterns assuming a modeled vehicle charged to 100% at home

Conclusions

This first look at a large dataset of in-use fast charging data show that modeled behavior differs somewhat from actual. The in-use data show charging closer to home than previously modeled, suggesting a different use case than long trips or travel days. The distance to home suggests a few hypotheses. First, that some fast charge customers are using a fast charger for home charging, even if they have to pay. Secondly, many customers would not consider using their BEV80 for purposes far from home and instead choose another household vehicle. Third, free charging enhances the tendency to substitute home charging for fast charging. These results are early and must be backed up with survey evidence. These results are only applicable to the BEV80s that dominate the sample. However, the larger dataset shows promise to help establish how and why people fast charge. This understanding will help consumers, automakers, site owners, charging providers and government agencies effectively plan and use fast charging to advance electric vehicles.

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